Naval Facilities Engineering Command Southwest
1220 Pacific Highway, San Diego, California 92132-5190

FINAL

EXPLANATION OF SIGNIFICANT DIFFERENCE FOR OPERABLE UNIT 3 RECORD OF DECISION

INSTALLATION RESTORATION SITE 7 MARINE CORPS BASE CAMP PENDLETON, CALIFORNIA

June 16, 2010

AUTHORIZING SIGNATURES

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ACRONYMS AND ABBREVIATIONS

AM	Action Memorandum
AR	Administrative Record
ARAR	applicable or relevant and appropriate requirement
CAMU	Corrective Action Management Unit
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CERCLIS	Comprehensive Environmental Response, Compensation, and Liability Information System
CFR	Code of Federal Regulations
cfs	cubic feet per second
DC	direct current
DON	U.S. Department of the Navy
DTSC	California Department of Toxic Substances Control
EE/CA	Engineering Evaluation/Cost Analysis
ESD	Explanation of Significant Difference
ET	evapotranspiration
FFA	Federal Facilities Agreement
FS	Feasibility Study
IR	Installation Restoration
MCB	Marine Corps Base
MCL	maximum contaminant level
MW	megawatt
NAVFAC SW	Naval Facilities Engineering Command, Southwest
NCP	National Oil and Hazardous Substances Contingency Plan
NPL	National Priorities List
OSWER	(US EPA) Office of Solid Waste and Emergency Response
OU	Operable Unit
PAH	polynuclear aromatic hydrocarbons
PCB	polychlorinated biphenyl
PCMMP	Post-Closure Monitoring and Maintenance Plan
POLs	petroleum, oil, and lubricants
psf	pounds per square foot
PV	photovoltaic
RACR	Remedial Action Completion Report
RA	Remedial Action
RD	Remedial Design
RI	Remedial Investigation
ROD	Record of Decision
RWQCB	California Regional Water Quality Control Board

ACRONYMS AND ABBREVIATIONS (Continued)

SM	settlement monument
SVOC	semi-volatile organic compound
SWDIV	Southwest Division, Naval Facilities Engineering Command
USACE	United States Army Corps of Engineers
USC	United States Code
US EPA	United States Environmental Protection Agency
VOC	volatile organic compound
yd^3	cubic yards

1.0 INTRODUCTION

This Explanation of Significant Differences (ESD) describes proposed changes to the land use for Installation Restoration (IR) Site 7 (Box Canyon Landfill) specified in the Record of Decision (ROD) for Operable Unit (OU) 3 at Marine Corps Base (MCB) Camp Pendleton, California. The ROD for OU 3 was signed March 31, 1999 (Southwest Division, Naval Facilities Engineering Command [SWDIV], 1999). This ESD addresses specific changes to the cap on the landfill. The Department of the Navy (DON) is planning to install a 1.48 megawatt (MW) direct current (DC) solar photovoltaic (PV) panel system covering an area approximately six acres on the site to provide renewable electrical power to MCB Camp Pendleton's electric distribution system that provides power to the southern part of the Base (CH2M HILL, 2010). The solar PV panel system is not part of the current land use for IR Site 7; however, because the installation of the panels and/or their foundations may impact the existing evapotranspiration (ET) landfill cap, the DON has determined after consultation with the U.S. Environmental Protection Agency (U.S. EPA) to complete this ESD. Attachment 1, *Design Considerations Report, Box Canyon Landfill,* evaluates design-criteria (i.e., stability, settlement, drainage control, landfill gas control and the ET cover system including vegetation), documenting the evaluation, analyses, and design considerations and recommendations for installation of the solar PV panel system on the landfill (CH2M HILL, 2010). These proposed changes do not fundamentally alter the overall remedy for the site and are appropriately addressed in this ESD in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and National Oil and Hazardous Substances Pollution Contingency Plan (NCP).

1.1 Site Overview

IR Site 7, Box Canyon Landfill
MCB Camp Pendleton
San Diego County, California

Comprehensive Environmental Response, Compensation, and Liability Information System (CERCLIS) Number: CA2170023533
National Priorities List (NPL) Status: Active

Lead and support regulatory agencies involved with oversight of IR Site 7 are as follows:

- U.S. DON – Lead Federal Agency
- U.S. EPA – Lead Regulatory Agency
- California Department of Toxic Substances Control (DTSC) – Lead State Agency
- California Regional Water Quality Control Board (RWQCB) – State Support Agency.

The CERCLA, 42 U.S.C. § 9601 et. seq. and the NCP, 40 C.F.R. Part 300, et. seq. governs the identification, analysis and remediation of hazardous substances at MCB Camp Pendleton, which was placed on the NPL in 1989. A Federal Facilities Agreement (FFA), signed by the DON, the U.S. EPA and the State of California on October 24, 1990, provides a blueprint for the remediation process conducted pursuant to CERCLA at MCB Camp Pendleton. The DON implements CERCLA pursuant to the FFA in partnership with the U.S. EPA, DTSC, and the RWQCB as members of the MCB Camp Pendleton FFA Team. Pursuant to the FFA, the DON maintains responsibility for the assessment and remediation of IR sites at MCB Camp Pendleton, with support from the FFA team. The US EPA provides regulatory oversight with input from the state agencies for all CERCLA remedial actions at MCB Camp Pendleton.

1.2 Summary of Need for ESD

This ESD is required by the CERCLA §117 (c), 42 United States Code (USC) §9617 (c) and the NCP 40 Code of Federal Regulations (CFR) §300.435 (c)(2)(i), because changes to the land use specified in the OU3 ROD with regard to the cap on the landfill have been proposed.

The purpose of this ESD is to document the significant changes to the land use outlined in the OU3 ROD for IR Site 7 and acknowledge that, based on analysis of the findings presented in the Revised Design Considerations Report (CH2M HILL, 2010) with appended Basis of Design, the proposed solar PV panel system can be designed so as not to adversely affect the remedy outlined in the ROD. As part of the final design of the selected solar PV panel system, technical analyses shall be performed to demonstrate that the system will meet the Design Considerations in Attachment 1.

1.3 Administrative Record

This ESD will become part of the Administrative Record (AR) for IR Site 7, in accordance with NCP 40 CFR §300.825(a)(2). The AR contains all information, data, and documents used to support the selection of the remedy for IR Site 7. It is the stand-alone legal source of information on the site. All documents supporting the remedial action decisions for IR Site 7 are located at Naval Facilities Engineering Command, Southwest (NAVFAC SW) and are available for review between 0830 and 1630 Monday through Friday. Advance scheduling to review documents is requested, or a request for copies may be sent in accordance with the Freedom of Information Act. The AR Point of Contact is as follows:

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1.4 Regulatory Guidance

The DON prepared this ESD in accordance with the following regulations and guidance:

- NCP 40 CFR, Part 300.
- *A Guide to Preparing Superfund Proposed Plans, Records of Decision, and Other Remedy Selection Decision Documents.* July 1999. US EPA, EPA 540-R-98-031, Office of Solid Waste and Emergency Response (OSWER) 9200.1-23P.
- *Guide to Addressing Pre-ROD and Post-ROD Changes*. April 1991. US EPA, EPA Publication 9355.3-02FS-4. OERR OS-220W.

2.0 SITE HISTORY, SITE CONTAMINATION, AND SELECTED REMEDY

2.1 Site History

A chronology of major events for IR Site 7 is provided in Table 1. IR Site 7, also referred to as Box Canyon Landfill, is located at MCB Camp Pendleton and was used for quarry operations from approximately 1946 to 1970 until it began Class III landfill operations in May 1974, and ended operations in 1984 (Figures 1 and 2).

It has been estimated that 1,093,000 cubic yards (yd^3) of municipal fill were placed in the landfill during this period. The landfill accepted municipal solid and nonhazardous waste and included household and construction refuse consisting of tree and lawn clippings, scrap lumber and metal, appliances, furniture, paper, fill, dirt, asphalt, concrete, tile, cans, containers, magazines, and boxes (SWDIV, 1999). The landfill reportedly received dry cleaning sludge containing Stoddard solvent, and contaminated soil and dumpster waste containing fuel (petroleum, oil, and lubricants [POLs]), solvents, thinners, strippers, epoxies, sealants, paint wastes, and chemical cleaners (SWDIV, 1999)

In 1995, the DON designated Box Canyon Landfill as a Corrective Action Management Unit (CAMU) for the purpose of consolidating remediation wastes from various MCB Camp Pendleton IR sites (SWDIV, 1995a). Approximately 39,400 yd^3 of chemically-stabilized, metal-impacted soil generated from CERCLA removal actions at IR Sites 3 and 6 conducted from 1996 to 1997 were placed into the designated CAMU (CAMU 1) (SWDIV, 1997a, 1997b. 1999) at IR Site 7. In addition, approximately 235,000 yd^3 of pesticide-impacted soil from CERCLA remedial actions conducted at IR Sites 1A, 1E, 1F, and 2A were placed into a second designated CAMU (CAMU 2) at IR Site 7 as directed in the OU-3 ROD (SWDIV, 1999, 2000, 2003a, 2003b. 2003c) (Figure 2).

2.2 Site Contamination

A remedial investigation (RI) was conducted at IR Site 7 from March 1993 through March 1994 to determine the potential for offsite gas migration and the potential impact to groundwater (SWDIV, 1995b). The RI included the collection of soil, groundwater, and air samples (SWDIV, 1995b). Groundwater samples were analyzed for metals, volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), gasoline, diesel, pesticides, polychlorinated biphenyls (PCBs), and water chemistry parameters. In general, groundwater impacts were found in wells downgradient of the site. However, the impacts were mostly at or below the maximum contaminant levels (MCLs) (SWDIV, 1995b). Low concentrations of polycyclic aromatic hydrocarbon (PAH) and VOCs were detected in soil. Results of the soil gas samples indicated that the potential for gas migration would not be a concern (SWDIV, 1995b).

Post-closure groundwater monitoring was initiated in 2003 for the purpose of determining whether groundwater was being affected by leachate or gas from the landfill. Currently, groundwater monitoring is being conducted on an annual basis at IR Site 7. In April/May 2009, groundwater levels and concentrations of previously detected contaminants were consistent with historical results (Trevet, 2010). Seven VOCs were detected in groundwater immediately downgradient from the landfill, however, concentrations did not exceed MCLs. Concentrations of 1,2-dichloroethane however were detected in two wells and did exceed the MCL of 0.5 µg/l. Detected concentrations of VOCs may indicate that landfill gas is affecting the groundwater

Table 1. Chronology of Major Events for IR Site 7

Description of Event	Date
Landfill operation started	May 1974
Landfill operation ceased	May 1984
NPL listing of MCB Camp Pendleton	November 1990
FFA signed and established	October 1990
Remedial Investigation (RI) (Group B Sites)	March 1993 to March 1994
Baseline groundwater quarterly monitoring	March 1993 to July 1995
Engineering Evaluation/Cost Analysis (EE/CA)	September 1995
Construction of CAMU I	May to December 1996
Addendum to 1995 EE/CA	June 1997
Action Memorandum (AM) for non-time-critical removal action	September 1997
CAMU I interim cover construction	October to December 1997
Feasibility Study (FS) OU-3	May 1998
ROD OU-3	January 1999
Construction of CAMU II	July to December 1999
Remedial Design (RD)	August 2000
Remedial Action (RA) work plan	June 2001
Remedial construction (Phase I) started	July 2001
Baseline landfill gas monitoring	August to September 2001
Phase I construction completed	January 2002
Postclosure landfill gas monitoring started	April 2002
Remedial construction (Phase II) started	August 2002
Phase II construction completed	December 2002
Post-closure groundwater monitoring started (quarterly)	February 2003
Five-Year Review	March 2004
Remedial Action Completion Report (RACR)	April 2004
Landfill Gas Extraction Pilot Study Work Plan	April 2007
Final Post-Closure Monitoring and Maintenance Plan (PCMMP)	October 2008
Five-Year Review	April 2009

CAMU – Corrective Action Management Unit
FFA – Federal Facility Agreement
IR – Installation Restoration
MCB – Marine Corps Base
NPL – National Priorities List

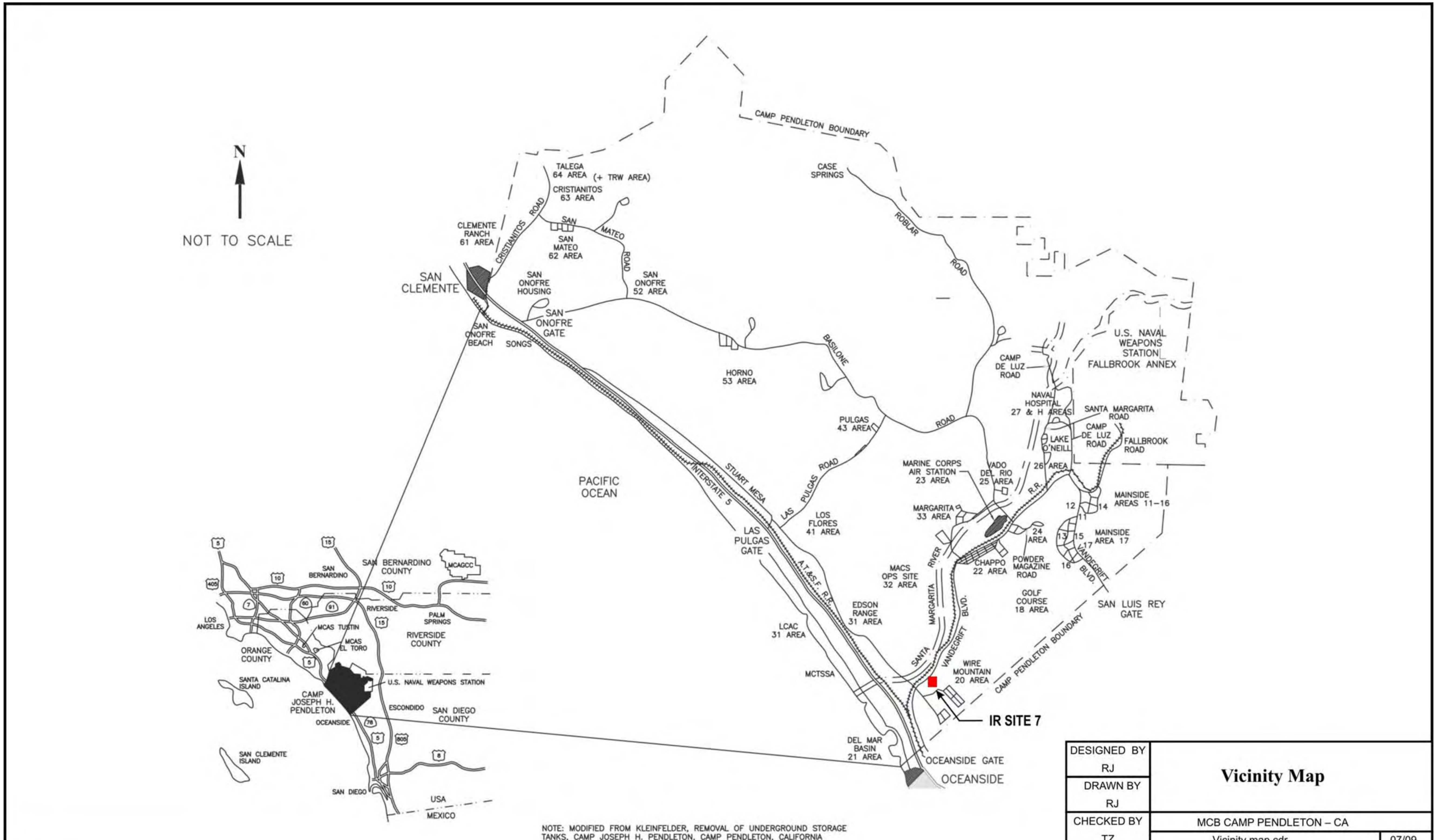

Figure 1. Vicinity Map.

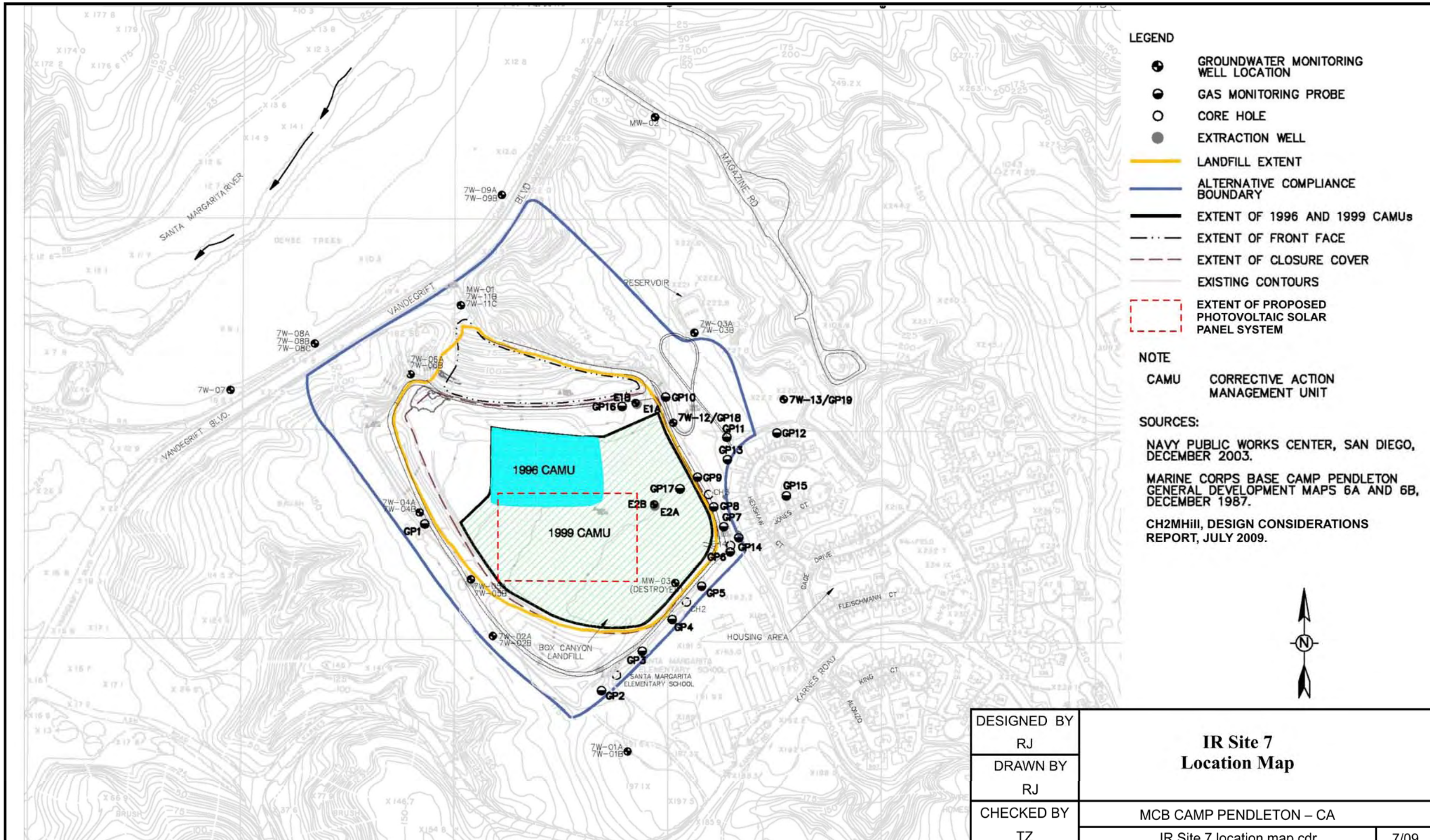

Figure 2. IR Site 7 Location Map.

beneath the landfill. The trends in VOC concentrations through time indicate that VOC concentrations have remained stable and low (Trevet, 2010).

Post-closure landfill gas monitoring was initiated in 2001 to assess the potential of landfill gas migration. Landfill gas monitoring is being conducted per the revised Final Post-Closure Monitoring and Maintenance Plan (PCMMP) (NAVFAC SW, 2008). The landfill gas monitoring network consists of 32 probes installed at various depths in 15 wells: 11 along the site boundary and four located outside the IR Site 7 compliance boundary and have been monitored at least bimonthly since they were installed. Currently, concentrations of methane in two shallow perimeter landfill probes located at the property boundary nearest the Wire Mountain Military Housing development have remained below detection limits since monitoring began in 2005. One other perimeter monitoring probe near the boundary by the Wire Mountain Military Housing development, GP-9, continues to be near the 5 percent by volume State compliance criterion. There is a monitoring probe, GP-10, which has been at or above State compliance levels; however, the agencies agreed that since the probe was so close to the waste, it did not qualify as a compliance probe (Battelle, 2009). agencies agreed that since the probe was so close to the waste, it did not qualify as a compliance probe (Battelle, 2009).

2.3 Selected Remedy

Based on the nature of the wastes disposed at IR Site 7, a remedial action to cap the landfill was proposed in the Group B RI (SWDIV, 1995b) and selected as the final remedy as stipulated in the OU-3 ROD (SWDIV, 1999), and included the following elements or "closure components":

- Installation of an ET cover that utilizes the natural process of surface runoff, storage, evaporation, and transpiration to control infiltration of water through the landfill cover. The cover would consist of a 1-foot-thick vegetated topsoil layer, a 4-foot-thick minimally compacted soil layer, and a 1-foot-thick compacted low-permeability bottom layer;
- Installation of lined drainage ditches between landfill benches on the north face of the landfill. Landfill benches (or terraces) are features designed and built into the side slopes of a landfill to minimize erosion by dissipating water flow energy;
- Post-closure maintenance requirements;
- Long-term groundwater monitoring; and
- Land use controls. No breaching of the soil cap may occur without prior approval of the FFA signatories.

A site-specific Remedial Design (RD) [U.S. Army Corps of Engineers (USACE), 2000] and a Remedial Action (RA) work plan (OHM, 2001) were developed to meet the OU-3 ROD requirements discussed above and included the design evaluations and analyses for the closure components (final cover system, final grading, stormwater and erosion control system, revegation, landfill gas, site security, and environmental monitoring systems). The final remedial action for IR Site 7 was implemented in accordance with the RD and RA work plan in 2001 (ET cover construction) and 2002 (drainage system, appurtenant structures, and final site revegetation). A Remedial Action Completion Report (RACR) was prepared to document the RA details in accordance with US EPA guidance for preparing final RA reports (Shaw, 2004). Land Use Controls (LUCs) stipulated in the 1999 OU-3 ROD for IR Site 7 are included in the final revised PCMMP (NAVFAC SW, 2008).

3.0 BASIS FOR ESD

As discussed above, a solar PV panel system is proposed to be built on the cap of the Box Canyon Landfill. Because the solar PV panel system was not contemplated at the time of landfill cap construction, nor discussed in the OU-3 ROD (SWDIV, 1999), it represents a change to the land use but does not fundamentally alter the overall remedy for the site (US EPA, 1999).

The RD evaluations and analyses discussed in Section 2.3 for the closure components were based on post-closure land use conditions which did not consider structures of any type on top of the landfill. An evaluation of each of these closure components was performed as part of the development of the Revised Design Considerations Report (CH2M HILL, 2010) (Attachment 1). The analyses and calculations for the proposed Box Canyon Landfill solar PV power system design were prepared by AECOM and is included in the Basis of Design (AECOM, 2010) which is appended to the Design Considerations Report. Preliminary evaluations took into account the impact of the proposed approximately six-acre solar PV panel system on top of Box Canyon Landfill, including a geotechnical analysis to evaluate bearing capacity, settlement, and stability issues. Also, preliminary erosion and drainage analyses were performed to support the development of the design considerations. Based on these preliminary analyses, discussed in further detail in Section 4.0, it was determined that a solar PV panel system would not directly impact the closure components. The findings of all analyses and evaluations are documented in Attachment 1, *Revised Design Considerations Report, Box Canyon Landfill* (CH2M HILL, 2010). As part of the design of the specific solar PV panel system to be installed, final analyses will be conducted by the solar PV panel system vendor, selected by the DON, to demonstrate that the Revised Design Considerations in Attachment 1 are achieved and verify that the performance of the ET cover system at the Box Canyon Landfill will not be adversely affected by the installation, operation, and maintenance of the solar PV panel system.

4.0 DESCRIPTION OF SIGNIFICANT DIFFERENCES

The difference that is proposed for this site is placing structures on the landfill which changes the post-closure land use. Prior to evaluating any potential impacts to Box Canyon Landfill and the remedy outlined in the OU 3 ROD, assumptions regarding the solar PV panel system were updated based on the proposed design (CH2M HILL, 2009) and include:

- The 1.48 MW DC solar PV panel system will be grid-tied, ground-mounted, and fixed tilt and distributed over approximately six acres on top of the landfill.
- Approximately 6,300 solar PV modules will be installed.
- For the purpose of calculating the effects of drainage and erosion caused by the impervious panels, each solar PV module has dimensions of 64.6 x 39.1 x 1.8 inches and weighs approximately 44 pounds.
- A PV rack will be supported by 4 precast concrete ballasts each with a gravel base for foundation and adjustable frame to support the PV modules. The PV rack will also consist of 28 PV modules and have a 15 degree tilt from horizontal and oriented 190 degrees (southerly direction).
- PV modules will be arranged in an array with a one-inch gap between modules to minimize the volume of runoff along one edge.
- PV racks will be arranged in rows that will be spaced 10 feet apart and each row will arrange the PV racks 30 inches apart.

- The width of each isolated concrete ballast to support the PV panels will be approximately 1.5 feet wide by 10 feet long and centered on top of 2 feet by 10.5 feet gravel bed.
- Foundation supports will be above ground (no penetration of the cover) and consist of a gravel bed approximately 10 inches thick.
- Power inverter will not be located within the limits of the landfill waste or on the side slopes of the landfill.
- Previous analyses performed for the Box Canyon Landfill closure design are assumed accurate and provide design criteria for evaluating the existing landfill components with a solar PV power system.

Installation of solar PV panels on top of Box Canyon Landfill will affect the following five identified landfill components: cover structure, vegetation, drainage, erosion, and monitoring. Solar PV panels will be set on a gravel bed on top the ET cover structure, affecting this landfill component by imposing additional bearing pressures, settlement, and impacting stability. Vegetation underneath the proposed impervious solar PV panels could be affected because the panels will shade the grasses, requiring a change to the original vegetation material in the footprint of the proposed solar PV panel array. Drainage could be affected because approximately 2.7 acres of impervious panels will span approximately six acres of the landfill, which could potentially change how runoff will occur during rain events. There is potential for erosion because soil loss due to blockage, ponding, or channeling of runoff during rain events around supporting footers will change from the original design if a structure is set on top of the landfill. The monitoring component of the landfill remedy may be affected because Settlement Monument 2 (SM-2) is located within the footprint of the proposed solar PV panel system. A settlement monument is a benchmark (typically made of brass) that is set in concrete and periodically surveyed using conventional survey techniques to monitor changes in elevation due to landfill settlement. A summary of these five original landfill components and the changes to them as a result of the installation of the solar PV panel array are discussed in Table 2.

Table 2. Summary of Five Original Landfill Components to be Modified.

	Original Site	Modified Site
Cover Structure	▪ A six-foot-thick evapotranspiration (ET) cover that minimizes infiltration of precipitation to the underlying landfill was installed.	▪ The six-foot-thick ET cover will remain in place and intact. Although the installation of solar PV panels will alter the measures in place to minimize infiltration, these alterations will not affect the ET cover to function as it was designed. The effect on evaporation of the transpiration process of the ET cover is not anticipated to be significant. The expected evaporative zone depth for this area, soil type, and vegetation is 60 inches. However, a rooting depth of 30 to 40 inches was conservatively used in the original HELP modeling and the cover was designed on this basis. ▪ Footers to support the solar PV panels on firm soils will have a nominal bearing pressure of 950 pounds per square foot (psf) and should not compromise the integrity of the ET cover system. Final bearing pressures and impacts to the ET cover system shall be verified during final design. ▪ The total localized settlement of a footing that would support a solar PV panel is estimated to be less than one inch when placed on firm soils. Differential settlement is expected to be about one half of the total settlement value. Settlement impacts shall be verified during final design and layout of the system. ▪ The south slopes of the landfill, where the solar PV panels are proposed, would meet the minimum factor of safety requirements for stability under static conditions when the solar PV panels are placed at a minimum offset of 15 feet from the edges of the slopes. Seismic displacement of the slopes is not expected to exceed two inches. Stability impacts to the ET cover system will be verified during final design and layout of the PV system.

Table 2. Summary of Five Original Landfill Components to be Modified (continued).

	Original Site	Modified Site
Vegetation	▪ Revegetation was completed in order to maintain integrity of the cover and limit infiltration.	▪ Revegetation material shall be native and shade tolerant to ensure survival in the shade of the solar PV panels and provide erosion protection for the landfill cover system. Plant species considered for revegetations are: Artemisia Californica Baccharis Pilularis Dichelostemma Capitatum Encelia Californica Eriophyllum Confertiflorum Eriogonum Fasciculatum Hemizonia Fasciculate Isocoma Menziesii Lasthenia Californica Layia Platyglossa Lessingia Filaginifolia Lupinus Bicolor Mimulus Aurantiacus Nassella Pulchra Salvia Apiana Salvia Mellifera Sisyrichium Bellum ▪ Vegetation would not require irrigation since they are drought tolerant. ▪ Vegetation shall not cover the settlement monuments.
Drainage	▪ The drainage channels have a design capacity of 11 cubic feet per second (cfs).	▪ The PV panel array will span four drainage basin areas of the landfill cover. A runoff maximum of 5.4 cfs was predicted from one of the drainage areas where the solar panel array system will be installed. The peak discharge from the PV panels on each drainage basin area is below the allowed design capacity for the drainage channel.
Erosion	▪ Soil loss was estimated to be approximately 0.45 to 0.64 ton per acre per year.	▪ Soil loss with a solar PV panel system on the landfill is predicted to be about 0.52 ton per acre per year. EPA regulations stipulate a maximum of two tons per acre per year.

Table 2. Summary of Five Original Landfill Components to be Modified (continued).

	Original Site	Modified Site
Monitoring	▪ Monitoring of landfill gases, groundwater, surface vegetation, earthen cover, settlement, and drainage structures	▪ Monitoring of earthen settlement may be affected as settlement monument SM-2 is located within the footprint of the proposed solar PV panels. Design of the PV array shall ensure that SM-2 is accessible for surveying. Installation of the solar PV panel array will not interfere with the other post-closure monitoring programs because the array will physically not affect any monitoring component.

The five landfill components (the cover structure, vegetation, drainage, erosion, and earthen settlement monitoring) could potentially be affected by the proposed solar PV panel system because the original landfill design (and post-closure end use) did not account for the installation of any structures. However, the solar PV panel system will have minimal impact on these five components assuming that the final design includes and meets all of the preliminary design considerations.

5.0 REGULATORY AGENCY COMMENTS

A summary of agency comments on the ESD are included in Attachment 2. It should be noted that a similar PV system was installed at Fort Carson Landfill, Colorado. Fort Carson is a U.S. Army installation located immediately south of Colorado Springs in El Paso County, Colorado. The site is a 15-acre former landfill that contains mostly construction debris. In 2007, the site was prepared for the solar facility by installing a four-foot-thick earthen envirotranspiration cover, and revegetated with drought-resistant prairie grass. The two-megawatt, ground-mounted PV solar facility covers 12 acres and is the largest solar array built at a US Army facility. There has been no issues with vegetation or drainage. More information is provided at http://www.epa.gov/oswercpa/docs/success_fortcarson_co.pdf.

6.0 STATUTORY DETERMINATIONS

This ESD recognizes the changes to the land use for the Box Canyon Landfill, consisting of installation of solar PV panels on the ET cap, remains protective of human health and the environment, and complies with federal and state applicable or relevant and appropriate requirements (ARAR) per CERCLA §121 and the OU-3 ROD.

7.0 PUBLIC PARTICIPATION COMPLIANCE

In accordance with the public participation requirements set forth in NCP §300.435(c)(2)(i), the DON published a Notice of Availability and a brief description of this ESD in a local newspaper as well as the MCB Camp Pendleton website. The ESD was made available to the public in the AR (see page 2, Section 1.4) and the Information Repository located at the Oceanside Public Library. The DON received no comments on the ESD during the 30 days from the date of the Notice of Availability (April 16 to May 15, 2010).

8.0 REFERENCES

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ATTACHMENT 1

Final
Design Considerations Report
Box Canyon Landfill

Final Revised

Design Considerations Report Box Canyon Landfill

Prepared for

Marine Corps Base Camp Pendleton and Naval Facilities Engineering Command Southwest (NAVFAC SW)

June 2010

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Santa Ana, California 92707

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This Design Consideration Report has been prepared under the supervision of Marielle Coquia, P.E. (Registered Civil Engineer C54906), whose seal as a Registered Professional Engineer in the State of California is affixed below. This Revised Final Design Consideration Report has been updated to report actual results of the analyses conducted by AECOM to support the design of the proposed solar PV system. The information presented in this report reflects the information and design developed by AECOM.

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Acronyms

AC	alternating current
AC/S, ES	Assistant Chief of Staff, Environmental Security
APCD	Air Pollution Control District
BMP	best management practice
BOD	Basis of Design
CAMU	Corrective Action Management Unit
CCR	Code of California Regulations
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
Cfs	cubic feet per second
CL	concentration limit
cm/s	centimeters per second
CMP	corrugated metal pipe
COC	constituent of concern
CP	compliance period
DC	direct current
DDD	dichlorodiphenyldichloroethane
DDE	dichlorodiphenyldichloroethene
DDT	dichlorodiphenyltrichloroethane
EPA	United States Environmental Protection Agency
ESD	Explanation of Significant Difference
ET	evapotranspiration
EZ	evaporative zone
FFA	Federal Facilities Agreement
FS	factor of safety
HEC	Hydrologic Engineering Center
HELP	Hydrologic Evaluation of Landfill Performance

H:V	horizontal to vertical
IR	Installation Restoration
IR Site 7	Box Canyon Landfill
kW	kilowatt
LFG	landfill gas
LUC	land use control
MCB	Marine Corps Base
MCE	Maximum Considered Earthquake
MP	monitoring point
MSW	municipal solid waste
MUSLE	Modified Universal Soil Loss Equation
MW	megawatt
OU	Operable Unit
PCMMP	Postclosure Monitoring and Maintenance Plan
Permit	General Industrial Storm Water Permit No. CAS000001
POC	point of compliance
POL	petroleum, oil, and lubricant
Psf	per square foot
PV	photovoltaic
PVC	polyvinyl chloride
RA	remedial action
RD	remedial design
RI	Remedial Investigation
RI/FS	Remedial Investigation and Feasibility Study
ROD	Record of Decision
RUSLE	Revised Universal Soil Equation
RWQCB	Regional Water Quality Control Board
SDHM	San Diego Hydrology Manual
SWPPP	Stormwater Pollution Prevention Plan

USACE	United States Army Corps of Engineers
UV	ultraviolet
y^3	cubic yards

SECTION 1.0

Introduction

1.1 Introduction and Purpose

This Design Considerations Report has been updated to present the design considerations for the Box Canyon Landfill for the purpose of supporting the Marine Corps Base (MCB) Camp Pendleton (Figure 1) in its efforts to permit, design, and build a 1.48-megawatt (MW) direct current (DC) grid-tied ground-mounted solar photovoltaic (PV) power system on approximately 6 acres of the Box Canyon inactive landfill (Figure 2). The Box Canyon Landfill is an Installation Restoration (IR) site managed under a Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Record of Decision (ROD). Any construction that potentially alters the ROD solution will require Federal Facilities Agreement (FFA) Team approval. For the FFA Team to approve, a CERCLA Explanation of Significant Difference (ESD) will be required. The Design Considerations Report will be included in the ESD.

This Design Considerations Report includes evaluation of the design for the existing landfill cover and as-built documentation of the remedial design documents prepared for the Box Canyon Landfill, also referred to as IR Site 7. The objectives of this Design Considerations Report are to define the design considerations and provide performance criteria for stability, settlement, bearing capacity, drainage control, landfill gas control, and cover system including vegetation, as it pertains to the construction of a solar PV power system on the landfill. The analyses included in this Design Consideration Report include the analyses for the design and engineering of the proposed PV system.

This Design Considerations Report is organized as follows:

Section 1 – Introduction and Purpose. Provides a brief introduction to the project, its objectives, and general background

Section 2 – Existing Closure Configurations. Describes the existing closure configurations and the related engineering analyses performed

Section 3 – Development of Performance Criteria for the Solar Photovoltaic System. Describes the assumptions and engineering analyses performed to evaluate the existing landfill closure configuration with a solar PV power system on top of the landfill

Section 4 – Design Considerations and Criteria. Presents the design considerations and criteria for designing the solar PV power system on top of the landfill

Section 5 – References. Provides a list of reference material used

1.2 Site Location and Description

1.2.1 Location

MCB Camp Pendleton is located along the Pacific Coast, near the City of Oceanside, San Diego County, California (Figure 1). Box Canyon Landfill is located in the southwest portion of the Base, approximately 200 feet south of Vandegrift Boulevard and 0.5 mile northeast of the intersection of Vandegrift Boulevard and Stuart Mesa Road.Santa Margarita Elementary School is located on the southwest of the landfill, and Wire Mountain Military Housing Complex is adjacent to the landfill on the east (Figure 2). A chain-link fence separates the military housing and school from the landfill site.

1.2.2 Site History

Quarry operations at Box Canyon were conducted sometime between 1946 and 1970.
Box Canyon was converted to a municipal solid waste (MSW) landfill in May 1974, taking municipal solid waste from MCB Camp Pendleton and operated until May 1984 according to records of the office of the Assistant Chief of Staff, Environmental Security (AC/S, ES), MCB Camp Pendleton (USACE, 2000). The limits of the landfill are presented in Figure 3. During the 10 years of landfill operations, approximately 1,093,000 cubic yards (y^3) of fill (waste and cover soils) was placed in the landfill (USACE, 2000).

The landfill contains no bottom liner, leachate collection system, and until recently a landfill gas extraction system was installed as part of a pilot test. The landfill accepted MSW and nonhazardous waste. Typical wastes accepted by the landfill included household and construction refuse consisting of tree and lawn clippings, scrap lumber and metal, appliances, furniture, paper, fill, dirt, asphalt, concrete, tile, cans, containers, magazines, and boxes. The landfill reportedly received dry cleaning sludge containing Stoddard solvent, and contaminated soil and dumpster waste containing fuel (petroleum, oil, and lubricants [POLs]), solvents, thinners, strippers, epoxies, sealants, paint wastes, and chemical cleaners (USACE, 2000).

In 1990, Box Canyon Landfill was added to the Base IR Program as IR Site 7 and placed into Group B, which was planned for permanent closure (NAVFAC, 2008). The use of presumptive remedy developed by the United States Environmental Protection Agency (EPA) for the remediation of the CERCLA municipal landfill sites was recommended by the Remedial Investigation (RI) (Shaw, 2004). In 1996, remediation wastes from various IR sites were consolidated and put into Box Canyon Landfill as part of Corrective Action Management Unit (CAMU) operations.

The CAMU operations consisted of two phases (Figure 4). Phase I of CAMU operations, conducted in 1996, consisted of placing approximately 39,400 y^3 of inert waste from IR Sites 3 and 6. The next phase, conducted in 1999, placed approximately 235,760 y^3 of wastes from IR Sites 1A, 1E, 1F, and 2A in Box Canyon Landfill.

Sites 1A, 1E, and 1F were used by the Base between 1942 and early 1970s to burn refuse generated by Base operations. Site 2A is one of seven mess hall grease pits. In addition to mess hall grease, POLs might have been placed in some of the pits. Between June and

November 1999, Box Canyon Landfill received the following deposits (approximate measures):

- 93,093 y^3 from Site 1A
- 29,341 y^3 from Site 2A
- 59,085 y^3 from Site IE
- 55,250 y^3 from Site 1F

As part of the RI process at IR Site 7, the selected remedy was the evapotranspiration (ET) cover system. The remedy required the containment of the wastes, elimination of exposure pathways, and long-term monitoring and maintenance of the containment system. The remedy was incorporated into the Operable Unit (OU) 3 ROD, which required the following remedial actions (Battelle, 2009):

- Installation of the ET cover
- Installation of lined, surface-water drainage structures, and erosion control measures
- Construction of an access road
- Implementation of a postconstruction monitoring and maintenance plan
- Documentation of the remedial action process and quality control confirmation of test data and final as-built conditions

In January 1999, the OU-3 ROD issued the final remedy and associated land use control (LUC) requirements for IR Site 7. The final remedial design (RD) was completed and approved in August 2000, and the CAMU was closed with a 1-foot-thick interim cover in October 2000. In June 2001, the remedial action (RA) work plan was completed and approved. The remedial construction started in August 2001 and a 6-foot-thick ET cover was installed to close the CAMU and the landfill (Shaw, 2004). In December 2002, the ET cover was completed and revegetated, and the final closure of the landfill was completed in February 2003.

1.2.3 Existing Site Conditions

The Box Canyon Landfill is approximately 28 acres within a small and narrow canyon that originally discharged stormwater runoff northward into the Santa Margarita River basin (Figure 5). The landfill slopes to the north and ends approximately 1,000 feet from the Santa Margarita River channel (USACE, 2000). The landfill cover surface is relatively flat and is separated by drainage control berms and drainage systems, such as channels and perimeter ditches, to convey runoff to a storm drain system. The landfill cover (6-foot-thick soil ET cover) is also heavily vegetated with native plant species of brush and grasses. The existing conditions of the ET cover on the Box Canyon Landfill are presented in Figure 3.

Box Canyon Landfill is located near active faults—Rose Canyon Fault, Whittier-Elsinore Fault, San Jacinto Fault, and San Andreas Fault. Rose Canyon Fault Zone is approximately 5 miles to the southwest. Whittier-Elsinore Fault Zone is approximately 22 miles northeast of the landfill. San Jacinto Fault Zone is approximately 45 miles east of the landfill. San Andreas Fault Zone is approximately 70 miles northeast of the landfill (USACE, 2000).

1.3 Regulatory Background

As discussed above, the final remedy for IR Site 7 was stipulated in the January 1999 ROD for the OU-3 sites. The ROD was subsequently approved and signed by parties to the FFA during February and March 1999. RA activities for Box Canyon Landfill began in 2001 with the installation of the ET cover and in 2002 with installation of the drainage system, its appurtenant structures, and final site revegetation. All RA activities were completed in January 2003. Postclosure monitoring and maintenance started in February 2003 and are currently performed in accordance with federal, state, and local regulations.

SECTION 2.0

Existing Closure Configurations

This section presents a summary of the remedial design evaluations and analyses that were performed for IR Site 7 closure components. The evaluations and analyses performed for IR Site 7 were based on restricted postclosure land use conditions, which do not include a solar PV power system or any structures on top of the landfill. The existing landfill closure configuration consists of the following components:

- Final Cover System
- Final Grading
- Stormwater and Erosion Control System
- Revegetation
- Landfill Gas
- Site Security
- Environmental Monitoring Systems

2.1 Final Cover System

As part of the approved ROD for OU-3, an approximately 6-foot-thick ET cover was constructed on the 28-acre Box Canyon Landfill. The limits of the landfill cover are shown in Figure 6. The ET cover was designed to allow evaporation of water through the cap and transpiration through plants. It also requires low maintenance and repair. The Hydrologic Evaluation of Landfill Performance (HELP) computer model demonstrated that the 6-foot-thick ET cover performed equivalent to the prescriptive Title 27 cover requirements for minimizing infiltration of precipitation through the final cover system.

The ET cover consists of a minimum of 1 foot of vegetative soil layer, a 4-foot-thick layer of select fill, and a minimum 1-foot-thick layer of low-hydraulic conductivity—no more than 1×10^{-5} centimeters per second (cm/s) (Shaw, 2004). The evaporative zone (EZ) depth for the ET cover system varied between 30 and 40 inches. Using the default values for the San Diego area as a guide, the HELP model used a fair strand of grass and an EZ depth of 32 inches. Typically, the EZ depth is assumed equal to the rooting depth plus depth of capillary draw. The actual available EZ depth of the existing ET cover system is about 60 inches.

Also used was an SCS curve number of 79, based on grass cover in fair condition. This curve number is based on vegetation in fair condition (50 to 75 percent ground cover and not heavily grazed) and a hydrologic soil group of "C." As modeled, this resulted in an acceptable leakage rate of 0.441 inch per year, which is smaller than that of the prescriptive cover with its leakage rate of 0.567 inch per year (USACE, November 2000). The results of the HELP model showed that with each incremental increase in EZ depth, the leakage rate through the cover decreased.

The vegetative layer contains no waste and allows the vegetation to provide erosion protection for the top soil. Approximately 48,000 y^3 of the onsite Ysidora Flat stockpile soil was used to construct the vegetative cover layer. The Ysidora Flat soil was in a floodplain containing fertile soil, which promoted vegetative growth. The vegetation must have a rooting depth less than 60 inches, which is the combined thickness of the vegetative layer and the select fill layer.

The select fill layer consists of a 4-foot-thick layer of soil that is capable of retaining water to sustain the vegetative cover during dry periods and protect the underlying barrier from desiccation. Approximately 168,000 y^3 of select fill was constructed from soils imported from the 22 Area borrow site and from existing onsite soil stockpiles. The select fill was compacted to between 85 percent and 88 percent of the maximum density as determined by the American Society for Testing and Materials (ASTM) in its Method D1557.

2.2 Final Grading

2.2.1 Grading

The landfill is elevated about 150 feet above the Santa Margarita River basin. The surface of the landfill cover has a minimum slope of 3 percent to the north toward the Santa Margarita River. The top of the terrace has a maximum slope of 2 to 1 horizontal to vertical (H:V), the center terrace has a maximum slope of 2.5H:1V, and the bottom terrace has maximum slope of 2.7H:1V. The final slopes of the landfill were analyzed in critical areas (northern side) for slope stability under static and pseudo static conditions. The factor of safety (FS) under static condition resulted in acceptable FS of 1.856 (USACE, 2000). Under pseudo static conditions, the slope stability analysis resulted in a FS that was below acceptable ranges; therefore in accordance with CCR Title 27 requirements, a deformation analysis was performed which resulted in a deformation of approximately 6.3 inches which is within an acceptable range for cover systems (USACE, 2000). The final grading, vegetation, and drainage structures will reduce runoff velocities to limit soil erosion and prevent ponding (Figure 6).

2.2.2 Settlement

The RD included a settlement analysis conducted to estimate the amount of potential settlement due to decomposition and consolidation of the waste. The analysis was conducted based on the assumption that the waste placed in the landfill from 1974 to 1984 was approximately 100 feet thick and not well compacted consisting of mostly organic waste and CAMU waste . It was assumed that the CAMU waste within the landfill was estimated to be 10 feet thick and contained little organic waste. The analysis estimated potential landfill settlement of between 2.5 and 4.1 feet for a 30-year postclosure period, and because the landfill is more than 20 years old, most of the primary consolidation settlement should have occurred (USACE, 2000).

Two monuments were installed on top of the landfill to monitor the settlement of the cover (Figure 7). One of the monuments is installed on the slope face and is designated SM-1; the second monument is situated in the center of the landfill and designated SM-2.
Both markers were placed where settlement was assumed to be the highest. Topographic

surveys will be conducted every 5 years to evaluate settlement (USACE, 2000). Based on the recent topographic survey (NAVFAC, 2008), SM-1 has settled 4.3 inches and SM-2 has settled 2.4 inches between March 2002 and April 2008.

2.3 Stormwater and Erosion Control System

2.3.1 Drainage Systems

As part of the RD, the drainage and erosion control facilities on the landfill were designed to carry the peak discharge resulting from a 100-year, 24-hour storm event, as required by CCR Title 27 for a Class III landfill. Perimeter drainage ditches, swales, and drainage structures on the final landfill were designed based on open channel hydraulics. Concrete-lined trapezoidal ditches are used for perimeter drainage ditches. Within Box Canyon Landfill, the landfill cover has a total drainage area of approximately 31.8 acres. The total drainage area includes the landfill topdeck, sideslopes, perimeter channels, and adjacent drainage areas tributary to the perimeter channels. The drainage area includes the final landfill top deck, side slopes, the perimeter channels, and adjacent areas that contribute to the landfill perimeter channels. No drainage run-on from tributary areas occurs. The drainage and erosion control system for the closed landfill is presented in Figures 5 and 6.

As previously described, the landfill cover has a minimum slope of 3 percent on the top deck areas, a maximum slope of 3H:1V on the perimeter side slopes, and 2H:1V on the terrace slope. Six drainage channels are constructed on the top deck and two terrace channels on the benches to maintain an approximate maximum overland flow length of 350 feet that will minimize erosion. The maximum overland flow length is to prevent the sheet flow from concentrating into channelized flows that could cause rill erosion. Runoff from the landfill cover is collected in the top deck drainage channels, which are then routed to the perimeter channels that flow into the existing 54-inch corrugated metal pipe (CMP) near the northwest corner of the landfill (Figure 6).

The landfill cover is divided into 10 drainage areas by drainage separation berms (Figure 8). These drainage areas range in size from 1.2 acres to nearly 4 acres. The drainage berms were constructed approximately 2 feet high above the finished cover grade to achieve acceptable overland (sheet) flow distances and provide a desirable channel slope. Berms were also used around the landfill perimeter to prevent any water from flowing directly down the 3H:1V slopes. These berms are adjacent to the drainage cover channels and spaced at regular intervals of 500 feet to help intercept sheet flow (NAVFAC, 2008).

The landfill is groomed regularly and is graded to prevent ponding and to stop erosion rills from forming. The diversion channels are cleaned out prior to the rainy season to allow full usage of the design capacity. Berms are repaired as needed to channel runoff from erosion-prone area. Overside drains are repaired as needed to carry surface water from top deck areas to the perimeter drainage courses.

Construction of permanent perimeter drainage facilities was completed in 2002 (Shaw, 2004). All local drainage is directed by final graded slopes to the lower portion of the canyon. Grades on much of the final landfill top deck are relatively flat, with slopes less than 4 percent from east to west.

Within Box Canyon Landfill, the primary drainage features include landfill cover drainage channels, the cover side slopes chutes, cover perimeter channels, and the existing 54-inch CMP (Figure 6). All drainage from the top cover is conveyed to the adjacent perimeter channel (Figure 6). A peak flow of 11 cubic feet per second (cfs) was used as a drainage design parameter for the cover. The cover has V-shaped channels with 4H:1V side slopes and a maximum channel bottom slope of 0.015 feet per foot. The V-shaped channel depth is 1 foot. The drainage berm is 3 feet from the channel bottom. Flows that exceed the capacity of the V channel will be confined by the drainage berms.

The landfill cover side slope chutes were constructed to convey drainage from the top of the cover to the base of the side, where flow enters the perimeter channel. The side slope chutes have a slope of 3H:1V and a depth of 1.5 feet. The side slope chutes are grouted rock-lined channels to minimize erosion caused by concentrated flows.

The perimeter channels in the north and south are used to direct drainage from the cover side slope channels to an existing 54-inch CMP. The perimeter channels are trapezoidal with a bottom width of 4 to 6 feet and 3H:1V side slopes. The upper sections of the north and south cover perimeter channels are vegetated and have an erosion control mat to provide additional stability. Vegetated or earthen-lined channels are required to have a minimum 3H:1V side slope for the maintenance and stability of the channels. The north perimeter ditch was reconstructed in 2004 to optimize the drainage (BAI, 2005).

The existing 54-inch CMP begins near the northeast corner of the landfill and ends in the canyon floor just north of the landfill, draining into an open channel that directs the runoff to the Santa Margarita River (NAVFAC, 2008) (Figure 8).

2.3.2 Rainfall Analysis

The hydraulic evaluation for the Box Canyon Landfill was performed for the Remedial Design Report (USACE, 2000). The drainage systems were designed to carry the peak discharge resulting from the 100-year, 24-hour storm event as required by CCR Title 27.

Drainage features were estimated by the Rational Method and by a rainfall-runoff simulation using the Hydrologic Engineering Center (HEC) hydrologic modeling software HEC-1. The HEC-1 Model for the landfill perimeter channels that are not on top of the landfill were modeled as trapezoidal and maximum longitudinal slopes of 2 percent. Peak discharges and runoff volumes were estimated using the HEC-1 Model which based its minimum slope of 3%. The computed peak discharge for any individual cover area was 7.9 cfs for the 25-year event and 11 cfs for the 100-year event. The peak discharges for the entire landfill area were 69 cfs for the 25-year event and 95 cfs for 100-year event.

2.3.3 Erosion Control Systems

Erosion control systems help limit the amount of soil erosion caused by high runoff velocities. Typical erosion control systems include erosion control mats, straw mulch, check dams, and rock riprap. The erosion control systems for the final landfill configuration included vegetated channels, erosion control mats, rock riprap at the end of side chutes, shotcrete lining, and dense vegetation.

In the RD, a sediment erosion analysis was completed in 2000 for the final cover erosion controls. Erosion analyses were performed to evaluate the stability of the vegetated landfill cover channels. A maximum permissible velocity of 2.5 feet per second was assumed based on the channel slope and soil type present at the site. The permissible velocity of 2.0 feet per second for a bare earth channel consisting of fine sand and sandy silt was used for comparison purposes (USACE, 2000).

An erosion control mat was required to provide stability for vegetated channels. The erosion control mat is an ultraviolet (UV)-light stabilized polypropylene fiber. An erosion control mat was utilized for both the cover and perimeter channels (USACE, 2000).

Rock riprap is utilized where areas of turbulent flow occur or in areas where the slopes are steep. Riprap lining was required for both the north and south perimeter channels. Rock riprap lining was required for the south perimeter channel from downstream to the conduit, approximately 1,250 feet. Riprap lining was required at all grouted rock chute basins. Rock riprap lining was required for the lower 400 feet of the north perimeter channel with a slope of between 5 and 8 percent. Rocks in the riprap have a maximum diameter of 12 inches and are placed with a minimum layer thickness of 18 inches.

Shotcrete lining was required for the northeast ditch and the east perimeter channel because of the steep channel slope. Drainage channels in these areas are remote from the landfill cover.

As part of the hydrologic evaluation in the RD, a Revised Universal Soil Equation (RUSLE) analysis and a Modified Universal Soil Loss Equation (MUSLE) analysis were used to estimate the average erosion rate. The RUSLE analysis includes factors for rainfall, soil erodability, and topography. Based on values for all factors, the RUSLE analysis computed that about 0.24 to 0.34 tons per acre per year and 5.0 y^3 per acre of soil are lost over 30 years (USACE, 2000). The maximum annual soil loss rate determined for any cover area is 0.34 tons per acre per year after the landfill construction and vegetation was established. Allowable annual soil loss for municipal waste cover material is generally set at 2 tons per acre. The MUSLE analysis predicted the soil loss for a single event considering the design storm events of the 25-yr and 100-yr storm events. Sediment volumes estimated for both the 25-year and 100-year event, was 160 y^3 and 220 y^3, respectively (USACE, 2000).

2.4 Revegetation

The final cover surface of the ET cover was vegetated with a native-plant seed mix approved by the Base biologist and the U.S. Natural Resources Conservation Service. The seed mix, included in Table 2-1, provides the list of seeds as approved by the MCB Camp Pendleton Environmental Department, a mixture of which was placed on the landfill (BAI, 2005).

TABLE 2-1
Seed Mix Design

Scientific Name	Common Name
Artemisia Californica	California Sagebrush
Baccharis Pilularis	Coyote Bush
Dichelostemma Capitatum	Blue Dicks
Encelia Californica	Common Encelia
Eriophyllum Confertiflorum	Golden Yarrow
Eriogonum Fasciculatum	California Buckwheat
Hemizonia Fasciculate	Golden Tarplant
Isocoma Menziesii	Coast Goldenbush
Lasthenia Californica	Goldfields
Layia Platyglossa	Tidy-tips
Lessingia Filaginifolia	California Aster
Lupinus Bicolor	Miniature Lupine
Mimulus Aurantiacus	Bush Monkey Flower
Nassella Pulchra	Purple Needlegrass
Salvia Apiana	White Sage
Salvia Mellifera	Black Sage
Sisyrichium Bellum	Blue-eyed Grass

2.5 Landfill Gas

As part of the ROD, a landfill gas (LFG) collection/control system was not included in the cover system because an evaluation by the San Diego Air Pollution Control District (APCD) determined that the landfill does not have the potential to generate significant amounts of gas based on the estimated volume of waste and results of past gas monitoring results at the site (MCB CP, 1999). However, after recent pilot studies were conducted, an LFG extraction flare was installed at the north end of the landfill, and two extraction wells (E2A and E2B) were installed on top of the landfill (Figure 4).

2.6 Site Security

The site access and security controls are managed by a 6-foot-high chain-link fence and locked gates along the site perimeter (NAVFAC, 2008). The main gate is located via an access road that is off Vandergrift Boulevard. The gates are locked, and only authorized persons are allowed access to the landfill. Figure 7 shows the location of the perimeter fence.

2.7 Environmental Monitoring Systems

2.7.1 Gas Monitoring

A network of 19 wells with a total of 40 monitoring probes was installed at the perimeter of the landfill to monitor landfill gas migration (Figure 4). Post closure monitoring of landfill gas migration has been conducted on a bimonthly basis since 2002 (NAVFAC, 2008). Until recently, monitoring well GP-9 had emitted methane concentrations near the compliance criterion of 5 percent by volume, as established by the state. Methane concentrations from well GP-9 are now in compliance. Monitoring well GP-10 has detected methane emission concentrations that are at or above state compliance levels; however, agencies agreed that the monitoring well is so close to the waste, it did not qualify as a compliance probe (Battelle, 2009). Perimeter monitoring probes are mainly located outside the limits of ET cover. However, as part of an LFG pilot study, two extraction wells, E2A and E2B (Figure 4) were located on top of the landfill cover.

2.7.2 Settlement Monitoring

Two settlement monuments were installed on top of the Box Canyon Landfill (Figure 7) to monitor the amount of settlement on the cover. The monuments were installed and surveyed on January 2002. One of the monuments is installed on the slope face and is designated SM-1; the second monument is situated in the center of the landfill and designated SM-2. Both markers were placed where settlement was assumed to be the highest (USACE, 2000).

Based on the recent topographic survey (NAVFAC, 2008), SM-1 has settled 4.3 inches and SM-2 has settled 2.4 inches between March 2002 and April 2008. The settlement survey monuments will be surveyed twice a year for the first 5 years following installation (NAVFAC, 2008).

2.7.3 Groundwater Monitoring

There are 24 groundwater wells installed in 13 locations around or at the site (Figure 4). The ROD requires long-term groundwater monitoring. Most of the groundwater monitoring wells were sampled between 1993 and 1995 during the Remedial Investigation and Feasibility Study (RI/FS) phase of the IR program (NAVFAC, 2008). Groundwater monitoring was conducted quarterly starting in 1993 (USACE, 2000). In 2005, the regulatory community agreed that a less frequent monitoring schedule would be adequate after a review of the data collected (Battelle, 2009). The frequency of groundwater sampling is currently performed on an annual basis with an extended suite performed every 3 years (NAVFAC, 2008).

2.7.4 Postclosure Monitoring and Maintenance

The Postclosure Monitoring and Maintenance Plan included provisions for implementing postclosure health and safety, stormwater pollution prevention, landfill groundwater monitoring, gas monitoring, and cover maintenance requirements.

The Post-Closure Monitoring and Maintenance Plan (U.S. Navy, 2008) requires that best management practices (BMPs) be identified as regular maintenance, preventive maintenance, stormwater management practices (such as silt fences and erosion control mats), employee training, inspections, and monitoring.

The Postclosure Water Quality Plan establishes the requirements and procedures for post-closure quality monitoring of surface water, groundwater, and unsaturated-zone water. The postclosure water quality requirements include the installation of a water quality monitoring system, such as those for groundwater and surface water. Groundwater monitoring parameters include physical parameters, hazardous constituents, waste constituents, and reaction products. The ROD requires long-term groundwater monitoring. The monitoring frequency will be evaluated after 5 years to determine if additional monitoring will be required.

The requirements and protocols for monitoring landfill gas migration and surface emissions are established in the Postclosure Landfill Gas Monitoring Plan. The Postclosure Landfill Gas Monitoring Plan required the installation of a gas migration monitoring network to ensure that the former Box Canyon Landfill is in compliance with CCR Title 27 standards, such as compliance with the maximum concentration of methane gas level in the air and the use of measures to prevent or control exposure to toxic and/or carcinogenic compounds. The plan requires that the site be monitored at least quarterly each year for a 30-year period.

The Postclosure Maintenance Plan addresses the requirements and procedures for maintaining the landfill and the integrity of the cover system. The maintenance plan includes monitoring the settlement monuments, maintenance of the cover such as reseeding vegetation, and inspection and maintenance of drainage structures.

SECTION 3.0

Development of Performance Criteria for the Solar Photovoltaic System

This section describes the design analyses and assumptions to establish the design and performance criteria for installing a 1.48-MW DC solar PV (ground-mounted, fixed tilt) system on top of the existing closed Box Canyon Landfill. The results of the analyses and evaluations provide the design considerations and criteria for the solar PV system.

The analyses and calculations for the proposed Box Canyon Landfill solar PV power system design were prepared by AECOM and is included in the Basis of Design (BOD) (AECOM, 2010). Preliminary evaluations were performed to determine the design considerations and criteria critical to the Box Canyon Landfill. The following assumptions regarding the solar PV power system components have been updated based on the proposed design and are as follows:

- A 1.48-MW DC solar PV (grid-tied, ground-mounted, fixed-tilted) system will be distributed over 6 acres on top of the landfill (Figure 9)
- Approximately 6,300 solar PV modules will be required to provide 1.48 MW (DC) of power
- For purposes of calculating the effects of drainage and erosion caused by impervious panel areas, a panel module has dimensions of 64.6 x 39.1 x 1.8 inches and weighs approximately 44 pounds (this is based on a manufacturers catalog data sheet for a high-efficiency monocrystalline silicon PV module)
- A PV rack will be supported by 4 precast concrete ballast footings each with a gravel base for foundation and adjustable frame to support the PV modules. The PV rack will also consist of 28 PV modules and have a 15 degree tilt oriented 190 degrees
- PV modules will be arranged in an array with a one-inch gap between modules to minimize the volume of runoff along one edge.
- PV racks will be arranged in rows that will be spaced 10 feet apart and each row will arrange the PV racks 30 inches apart
- The width of the isolated ballast footings to support the PV panels, if used, will be approximately 3 feet
- The width of each isolated concrete ballast footing to support the PV panels will be approximately 1.5 feet wide by 10 feet long and centered on top of 2 feet by 10.5 feet gravel bed
- Foundation supports shall be aboveground (in other words, no penetration or excavation of the existing ET cover will be allowed) and consist of a gravel bed

- Power inverter will be located on an area that is located southeast of the landfill and south of the perimeter channel (not within the limits of the landfill waste or on the side slopes of the landfill)
- Only rigid metal conduit for DC source (solar PV system) to the power inverter will be used on top of the landfill and will be above ground.
- Rigid polyvinyl chloride (PVC) conduit from the power inverter to the power grid will be used outside the limits of the landfill and will be underground and be encased in concrete
- Previous analyses performed for the Box Canyon Landfill closure design are assumed accurate and provide the background design criteria for evaluating the existing landfill components with the solar PV power system

3.1 Geotechnical Analyses

Geotechnical data pertaining to the Box Canyon Landfill site from a previous report (USACE, 2000) were reviewed. The Basis of Design for the proposed design was prepared by AECOM (Appendix A) and included evaluating the bearing capacity for ballast footings to be placed above grade on the landfill cover, to support the solar panels. Settlements estimated with consideration of the proposed additional load from the PV array and ballast footing contact pressures. Stability analyses are performed considering the additional load from the PV solar panel system. Displacement potential of the slopes under seismic conditions is also evaluated. The pertinent geotechnical analyses performed by AECOM are included in Appendix A.

3.1.1 Bearing Capacity

Isolated ballast footings could be designed to support the loads from the PV solar panel system. Ballast footings shall be placed above the existing grade to preserve the integrity of the landfill cover system. The design calculations for the bearing resistance of the soil underlying the ballast footings is evaluated (Appendix A) using cohesion (C) of 42 pounds per square foot (psf) and-a friction angle (ϕ) of 20 degrees for the ET cover soil and a ϕ of 40 degrees for the ballast footing support gravel. An allowable bearing capacity of 600 psf is estimated. This bearing capacity accounts for assumed loads to resist the solar PV system's dead and live loads and provides sufficient foundation support to resist overturning and uplift stability due to applied seismic and wind loads at the site. Allowable bearing pressures were determined for the proposed design and construction with respect to the final layout, ballast footing size and locations (Appendix A). Suitable site preparation shall be performed to support the ballast footing without compromising the integrity of the ET cover system.

3.1.2 Settlement

Settlement estimates (Appendix A) as a result of the PV solar panel system placement were performed by AECOM based on the actual proposed ballast footing sizes and configurations.

The total localized settlement of the ballast footing that would support solar panels is estimated to be less than 1 inch (Appendix A). Differential settlements are not expected to exceed half of the total settlement values. These settlements are expected to occur during construction of the PV Panels. Waste degradation settlements, which are independent of the PV Panel loads, are expected to continue, as predicted in previous reports and on-going settlement monitoring will continue.

3.1.3 Stability

Static slope stability analyses included in Appendix A were conducted in accordance with CCR Title 27. A minimum factor of safety of 1.5 under static and pseudostatic conditions is required according to CCR Title 27. In lieu of a pseudostatic analysis, a slope deformation analysis can be performed. The results show that the analyzed landfill slopes are expected to be stable under static conditions. A minimum of offset of 15 feet for placement of PV panels from the slope edges might be needed for proper drainage, access and other considerations.

A slope deformation analysis (Appendix A) was completed in accordance with procedures presented by Makdisi and Seed (1977). Results indicate that one to three inches of slope deformation can be expected at the landfill slopes supporting the PV panels during a maximum considered earthquake (MCE) event.

Stability of the PV system was performed for the final design with respect to the final layout, ballast footing size, and locations, which is included in Appendix A.

3.2 Erosion/Soil Loss Analyses

A general soil-loss evaluation was completed based on assumptions and information, such as soil cover material, vegetation cover, and rainfall analysis presented in the RD for the Box Canyon Landfill and approved ROD. Soil loss due to the presence of the solar PV system is included in the Basis of Design Appendix A. The results are below the allowable soil loss of 2 tons per acre per year prescribed by EPA.Erosion concerns are addressed by providing spacing of modules within each of the panel racks or structures. A one inch gap is also provided between modules to minimize the volume of runoff along one edge. A project-specific soil loss analysis to confirm that the system will meet the design criteria was performed for the final design and is included in Appendix A.

3.3 Infiltration Analyses

The existing ET cover was designed to perform (at a minimum) equivalent to a regulatory "prescriptive" cover. The infiltration analyses performed for the ET cover as part of the RD and the approved ROD included the installation of a 6-foot-thick ET cover. As described previously, the ET cover consists of a minimum 1 foot vegetative soil layer, a 4-foot-thick select fill layer, and a minimum 1-foot-thick layer of low-permeability soil. The evaporative zone (EZ) thickness was conservatively assumed to be between 30 and 40 inches in the HELP modeling (USACE, 2000) which corresponds to an estimated vegetative growth of fair grass. Typically, the EZ depth is assumed equal to the rooting depth plus depth of capillary draw. The actual EZ depth of the existing cover system available for moisture storage and rooting is about 60 inches. Hence, because the HELP model assumes a fair grass, shading due to PV panels' placement is not expected to have an impact on the calculated infiltration of the existing ET cover system. It should also be noted that during construction the permeability test results for the in-place 1-foot-thick layer of low-hydraulic conductivity was determined to be approximately 1 $\times 10^{-6}$ cm/s (Shaw, 2004). No additional soils or decrease in cover thickness for installation of the PV panel systems would occur; therefore, an infiltration analysis (HELP modeling) was not necessary and not performed.

The list of native species that were chosen for the ET cover (Table 2-1) was based on the species present in the surrounding area. This was done in an effort to choose species that would naturally occur in this area. Review of the native species was performed by the Base biologist and determined that most of the species in Table 2-1 could thrive and tolerate partial to full sun and shade. A few were identified as possibly having concerns associated with location of planting (i.e. in between and under the arrays). Also, the shrubby species that were chosen generally grow 3-4 ft tall while the herbaceous species 1-2 ft tall, addressing the issue associated with height requirements.

The species that are not recommended for the ET cover with PV panels include:

Baccharis pilularis
Hemizonia fasciculatum
Salvia apiana
Salvia mellifera

3.4 Drainage Analyses

Using the drainage analyses performed as part of the RD for the landfill configuration, a drainage evaluation was conducted to evaluate the effects of installing an approximate 6-acre PV solar panel array on the top deck of the Box Canyon Landfill. Each panel module was assumed to have a surface area of approximately 64.6 x 39.1 square inches and a total of 6,300 panel modules would be used. The total impervious surface area of the PV modules is approximately 2.7 acres. Hydrologic analysis was conducted to predict the amount of runoff from an individual rack of PV panels. Each PV rack will have 4 horizontal drip lines with ¼ of the panel area contributing to each line. This is about 130 square feet of panel area resulting in less than 0.01 cfs per drip line. This amount of water is evenly spread out over the 38 foot long drip line resulting in a negligible impact to the surface below therefore no surface treatment is required beyond revegetation. Using the San Diego Hydrology Manual (SDHM), a 100-year, 24-hour storm event was used to evaluate the amount of runoff from the PV panels. For the analysis, it was assumed that the PV panels were 100 percent impervious, so a value for the runoff coefficient (C) was 1.0 and 0.25 was assumed for the existing landfill cover. A blended C value was used for the drainage areas. Drainage calculations are presented in the BOD (Appendix A). Based on the SDHM and a time of concentration of 17.5 minutes, the rainfall intensity for Box Canyon Landfill would be 2.94 inches per hour. Using the Rational Method in predicting the runoff introduced by the solar PV system, a maximum of 5.4 cfs of runoff was estimated for CS 2 (Appendix A). The PV panels will span over four existing drainage basin areas (Figure 8) of the landfill cover; therefore, there would be no impacts on the existing drainage channels. The drainage basin areas consist of CS 2, CS 3, CN 2, and CN 3, approximately 3.93 acres, 3.10 acres, 3.76 acres, and 3.04 acres, respectively. The existing drainage channels have a design capacity of 11 cfs. The corresponding peak discharge from the PV panels on each drainage basin area is below the allowed design capacity for the drainage channel. The drainage basin area CS 2 resulted in the largest discharge but was below the design capacity of the existing drainage channel.

A drainage analysis was performed to support the final design and is included in the BOD (Appendix A).

3.5 Monitoring System

The proposed area for the PV panels does not affect any of the existing landfill gas migration monitoring wells or existing groundwater wells. Existing monitoring wells are located near or at the perimeter of the landfill (Figure 4). Two LFG extraction wells are located on top of the landfill and on the east side (Figure 4).

Two settlement monuments are on the cover to monitor the settlement. Settlement monument 2 (SM-2) might be within the vicinity of the proposed area for the PV panels (Figure 5). The settlement monuments must not be covered and must be protected in place.

3.6 Site Access

There is an existing access road with Class II Pavement around the perimeter of the landfill and through the middle of the landfill. This access road must be maintained to allow access to the solar PV panels, as well as the maintenance of the solar PV system, vegetation, and existing drainage systems.

SECTION 4.0

Design Considerations and Criteria

This section describes the design considerations and criteria required for design and construction of a 1.48-MW DC grid-tied ground-mounted, fixed-tilt (15 degree tilt angle) solar PV power system on approximately 6 acres of the Box Canyon inactive landfill. The design considerations are not a design specification but rather provide guidance for the design/build team and shall be reviewed for compliance and regulatory requirements. The design considerations and criteria are based on the evaluation of the ET cover and drainage system in Section 3 above.

4.1 Geotechnical

Based on the results of the analyses and engineering evaluations in Section 3, an allowable bearing capacity of up to a maximum of 600 psf can be used for designing the ballast footings to support the proposed PV panels. Site preparation shall be performed without compromising the integrity of the ET cover system to support the ballast footings. The bearing pressure shall be verified in the field during construction.

Using the above design considerations, total localized settlement due to the ballast footing pressure is expected to be less than 1 inch, and the differential settlement is expected to be about one half the total settlement value. Settlement of PV solar panels is also possible due to waste degradation. This includes localized “sink-hole” or depression types of settlement that could occur in the landfill area as a result of consolidation, shifting, or degradation of waste buried in the landfill over a period of time. These settlements can neither be accurately predicted nor quantified. This should be considered a postconstruction monitoring and maintenance issue.

The south slopes of the Box Canyon Landfill, where the solar panels are proposed, shall meet the minimum factor of safety requirements for stability under static conditions when the PV panels are placed at a minimum offset of 15 feet from the edges of the slopes. Therefore, the PV panel system shall be offset by a minimum of 15 feet from the edge of the side slopes of the landfill. Seismic displacement of the slopes is not expected to range from 1 to 3 inches.

The above geotechnical conclusions are based on the PV panel configuration and existing site conditions.

4.2 Revegetation

Vegetation of the Box Canyon landfill is very well established. Revegetation of any disturbed or exposed areas shall provide erosion protection for the landfill cover system. Disturbed areas during construction must be stabilized with vegetation or covered. Postclosure maintenance of vegetation will prevent the contamination of stormwater sediment. Such maintenance would be done on all slopes, as well as drainage ditches, swales, and exposed flat surfaces as part of postclosure maintenance to protect the quality surface water.

The following revegetation requirements shall also be considered:

- Revegetation shall be with a native seed mix that shall be approved by MCB Camp Pendleton. The mix could include seed mix from the Weed and Reseed Plan for Box Canyon Landfill and excluding the following plants:
  Baccharis pilularis
  Hemizonia fasciculatum
  Salvia apiana
  Salvia mellifera
- Vegetation considered for reseeding must be low maintenance and must not block or cast shadow on the PV panels.
- The vegetation must not have roots that exceed the cover layer depth to the low-permeability layer below (cannot exceed 60 inches) or that could potentially damage the integrity of the cap.
- The vegetation must be shade tolerant, which would survive in the shade of the PV panels.
- Vegetation must not cover the settlement monuments because these monuments are used to monitor the settlement on the cover.

4.3 Infiltration Potential

The primary surface of the ET cover is to prevent precipitation and runoff from entering the waste and allow evapotranspiration of the precipitation from the rainfall event. Infiltration of the cover must be limited to prevent rainwater seepage into the waste, which would cause further decomposition of the waste and possible settlement of the cover. The following infiltration preventions shall be considered:

- There shall be no decrease of the ET cover thickness because it could lead to impairment of the performance of the ET cover system, such as increasing precipitation infiltration and creating a passageway for landfill gas migration.
- The EZ depth of the cover shall not be less than 30 inches and capable of supporting vegetation to help limit the amount of infiltration.
- The ET cover shall perform equivalent to the prescriptive Title 27 cover requirements for minimizing infiltration of precipitation through the final cover system.
- Vegetated channels shall be lined with erosion control mats to limit the amount of infiltration in areas of flat slopes.

4.4 Erosion Protection

Erosion of the cover shall be minimized. The overall erosion potential due to a solar PV power system of 6-acres (approximately 6,300 panel modules) is predicted to have minimal effect on the current site condition. In any case, the cover must be protected from excessive erosion to maintain its integrity. For erosion protection of the cover, the following erosion controls shall be implemented:

- Limit the use of rock riprap and maximize the use of the vegetated cover.
- Soil loss shall be less than 2 tons per acre per year per EPA regulations.
- For vegetated channels, an erosion control mat is required to maintain the channel stability.
- All rocks in channel riprap must have a maximum size of 12 inches in diameter with a minimum layer thickness of 18 inches.
- All aboveground ballast footings should be designed and constructed such that blockage, ponding, and/or channeling from runoff or erosion are prevented.

4.5 Drainage and Grading

The cover drainage and grading help divert surface runoff to limit soil erosion and prevent ponding from occurring. Maintaining minimum slopes and limiting the velocity of collected runoff will allow sheet flow of the runoff without eroding the top soil. Based on the analyses performed in Section 3.0, the flow from drip lines from the panel modules is expected to be minimal and the overall flow expected from the PV panels will not impact the capacity of the existing drainage channels. As part of the final design for the system, the design/build team shall conduct a project-specific drainage analysis to confirm that the system will meet the design criteria.

The following considerations shall be implemented:

- For drainage design, all existing drainage features (designed for the 100-year, 24-hour storm event) shall remain in place and unaltered by the solar PV power system.
- The maximum overland flow length for any drainage cover area is 350 feet. All drainage from the existing top deck of the ET cover is currently directed to adjacent perimeter channels.
- Existing drainage structures, shall have the capacity to carry peak flow from the 100-year, 24-hour storm event.
- The minimum slope for the top deck cover is 3 percent in the northwest direction and shall not be altered for the placement of the solar PV power system.
- All existing drainage berms must be protected to maintain the maximum overland flow length and to confine flow when flows exceed the V channel capacity.

- The maximum permissible velocity is 2.5 feet per second, based on channel slope and the easily eroded type of soil at the site.
- The drainage basin areas where the PV panels are to be located shall not exceed an impervious PV area of 3.93 acres.
- The maximum peak discharge to a top deck drainage channel from a tributary drainage basin area shall not exceed 11 cfs.
- Repairs to drainage structures or regrading shall be made immediately.
- Drainage structures shall be inspected prior to and during the rainy season to maintain the functionality of the structures.

4.6 PV Panel Configuration Design Criteria and Requirements

A set of PV panel modules will be installed on top of the existing cover. The configuration of the panel modules must not affect or change the functionality of the ET cover or interfere with the postclosure monitoring and maintenance of the ET cover and drainage systems. The ability of the Base to perform periodic inspections of the ET cover and make necessary repairs will not be affected. When configuring the placement of the PV panels, the following shall be considered for the design criteria:

- For foundation supports, site preparation shall be performed without compromising the integrity of the ET cover system. Based on the assumed PV system configuration and subgrade soil conditions used for design analyses, an allowable bearing capacity of 600 psf (AECOM, 2010) can be used. Verification of the allowable bearing capacity is required based on the actual PV system configuration and subgrade soil conditions.
- In designing the foundations for the PV system supports, the design/build team shall consider maximizing the ET cover area exposure (i.e., minimizing the size and number of the foundations) while ensuring the supports account for all loads, including seismic, sliding, and wind.
- Total localized settlement due to ballast footing pressures and solar panel surcharge shall not create ponding around the ballast footings.
- The solar PV power system shall be offset by a minimum of 15 feet from the crest of the side slopes of the landfill.
- PV panel configurations shall not block access or oversight views of settlement monuments.
- The existing landfill slopes shall not be altered for the placement of the solar PV power system. The existing top deck slope of the landfill varies and has a minimum slope of 3 percent in the northwest direction.
- Panels shall allow a minimum of 10 feet clearance space for an access road for postclosure activities for the landfill, which will include maintenance vehicles and equipment.

- Existing drainage facilities and grading shall not be disturbed or modified. Surface water runoff from the panels shall not create flows greater than the capacity of the existing drainage channels or create velocities that exceed 2.5 feet per second in the channels.
- Configuration of solar PV panel modules shall not create drip line flows with the potential of creating erosive velocities.
- Foundation supports of the PV panels shall not create blockage of the surface water drainage patterns and potential for ponding or erosion.
- The solar PV system shall not create or interfere with repairing low points (or ponding) on top of the ET cover.
- Monitoring wells, probes, and LFG extraction system as well as access to them shall not be blocked or disturbed by the solar PV power system.
- No building structures or enclosures shall be constructed within the limits of the landfill waste.
- PV equipment (inverters and transformer) shall not be located within the limits of landfill waste. The area southeast of the landfill and south of the perimeter channel shall be considered for location of the PV equipment and/or additional PV panels.
- Utility connections shall be aboveground and suitable for thermal expansion and contractions, sunlight, spark, and corrosion resistant; all fittings shall be sealed.
- Wiring from collector boxes and equipment shall not be buried in the ET cover. All conduits shall be surface mounted and physically protected. Maintenance vehicles shall be able to drive over the conduit system for access.
- Ground rods shall not be allowed within the limits of the ET cover.
- The grounding system on the ET cover shall not interfere with the performance of the ET cover system, including the vegetative layer (thickness and vegetative growth) and low-permeability layer, modify the existing drainage system, or impede access to the postclosure monitoring and maintenance activities of the ET cover system or operations and maintenance of the PV system.
- All structures, utilities, and grounding systems associated with the solar PV system shall not result in creating routes for water infiltration and an LFG migration route and/or create ponding or accumulation of surface water runoff.
- The PV contractor will be required to perform inspections and maintain the PV system and ET cover for 5 years. O&M will include inspecting the ET cover for any impacts due to the PV structures on the ET cover which will include observing the conditions of ponding, erosion, changes to drainage, settlement, cracking, and/or signs of stressed or sparse vegetation. Any signs of damage to the ET cap or PV system will be addressed and corrected by the PV contractor.
- In addition, MCBCP will continue postclosure monitoring and maintenance per the approved Postclosure Monitoring and Maintenance Plan (NAVFAC, 2006).

SECTION 5.0

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Figures

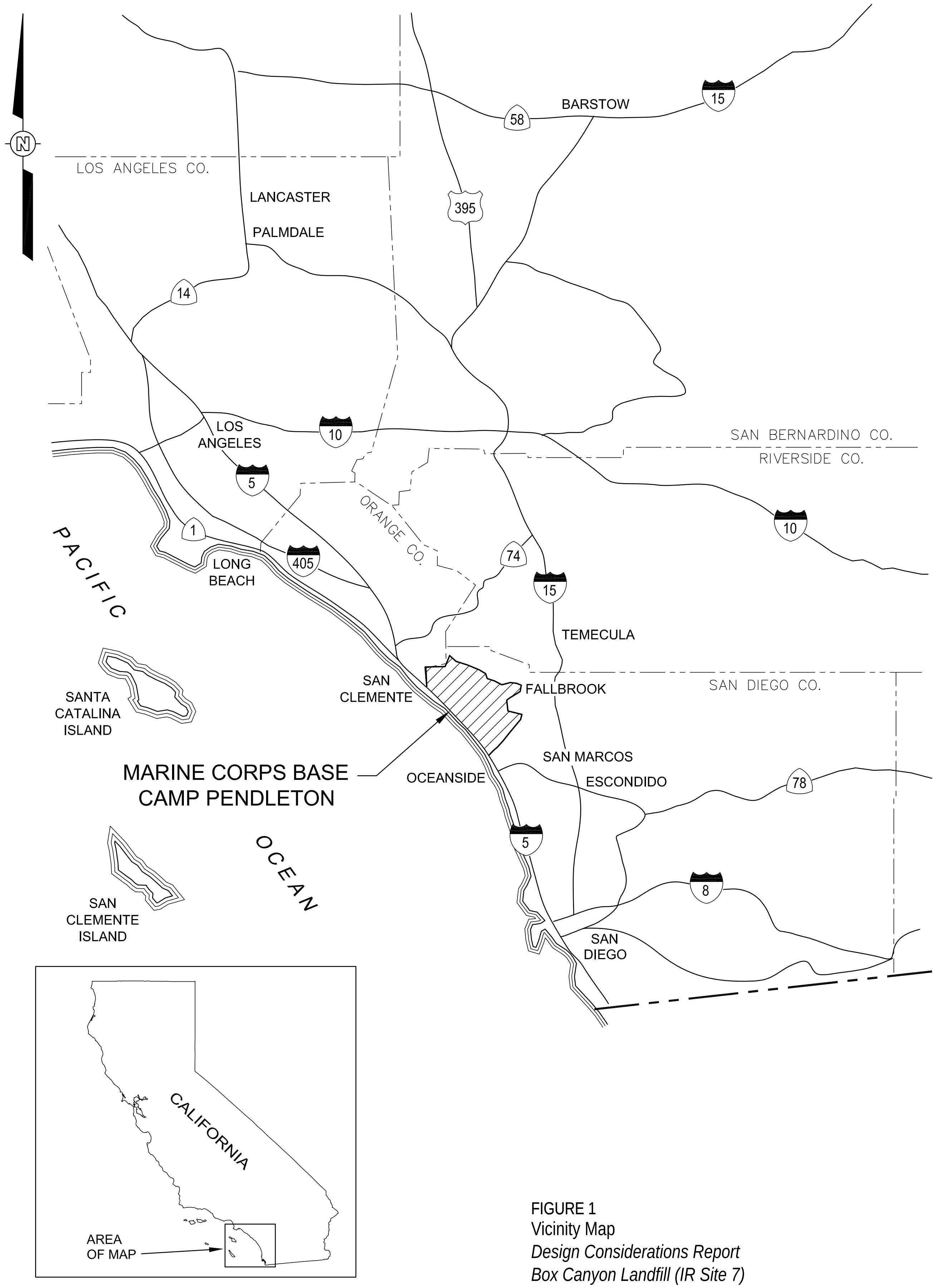


FIGURE 1
Vicinity Map
Design Considerations Report
Box Canyon Landfill (IR Site 7)
Marine Corps Base, Camp Pendleton, California
US Department of Navy Southwest Division
Naval Facilities Engineering Command

FIGURE REFERENCE:
"DRAFT FINAL REMEDIATION ACTION COMPLETION REPORT"
BY SHAW ENVIRONMENTAL, INC.
DATE: MARCH 12, 2004

SCO390401.TS.DB vicinity_map.ai 7/09

LEGEND

- Existing Utility Pole
- Transformer
- Proposed 12 kv Conductors
- Existing Electrical Line
- Proposed Photovoltaic Solar Panel Array

FIGURE 2
Site Location Map
Design Considerations Report
Box Canyon Landfill (IR Site 7)
Marine Corps Base, Camp Pendleton, California
US Department of Navy Southwest Division
Naval Facilities Engineering Command

FIGURE REFERENCE:
PRELIMINARY DESIGN PROVIDED BY MCB CAMP PENDLETON

GFI031110003753SCO390401.TS.DC solar_panel_v3.ai 3/11

CH2MHILL

Legend

Site Boundary

FIGURE 3
Existing Conditions
Design Considerations Report
Box Canyon Landfill (IR Site 7)
Marine Corps Base, Camp Pendleton, California
US Department of Navy Southwest Division
Naval Facilities Engineering Command

FIGURE REFERENCE:
"FINAL REVISED POST CLOSURE MONITORING AND MAINTENANCE PLAN IR SITE 7 BOX CANYON LANDFILL"
BY NAVFAC, SOUTHWEST DIVISION
DATE: OCTOBER 24, 2008

SCO390401.TS.DB site_location_plan.ai 7/09

CH2MHILL

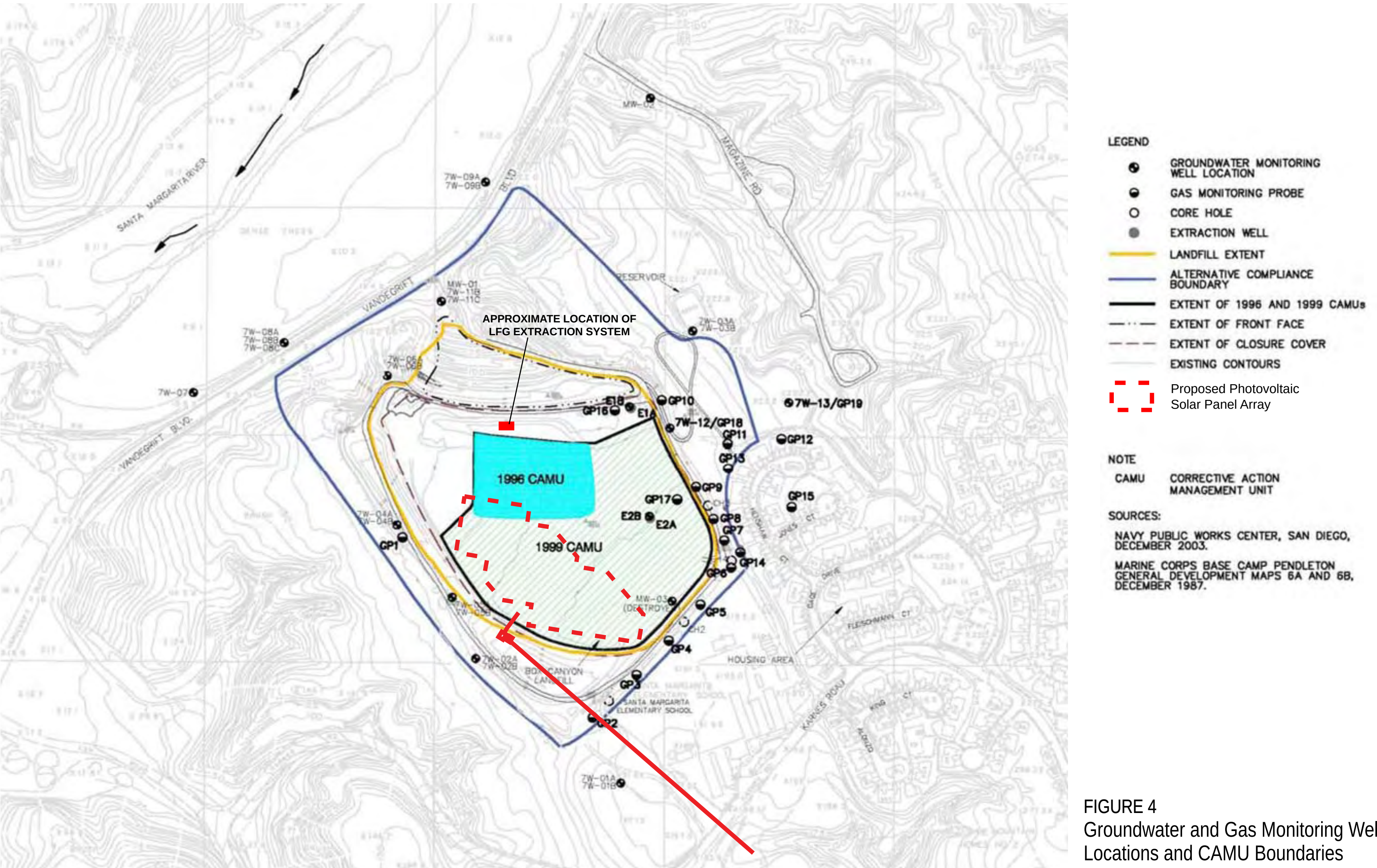
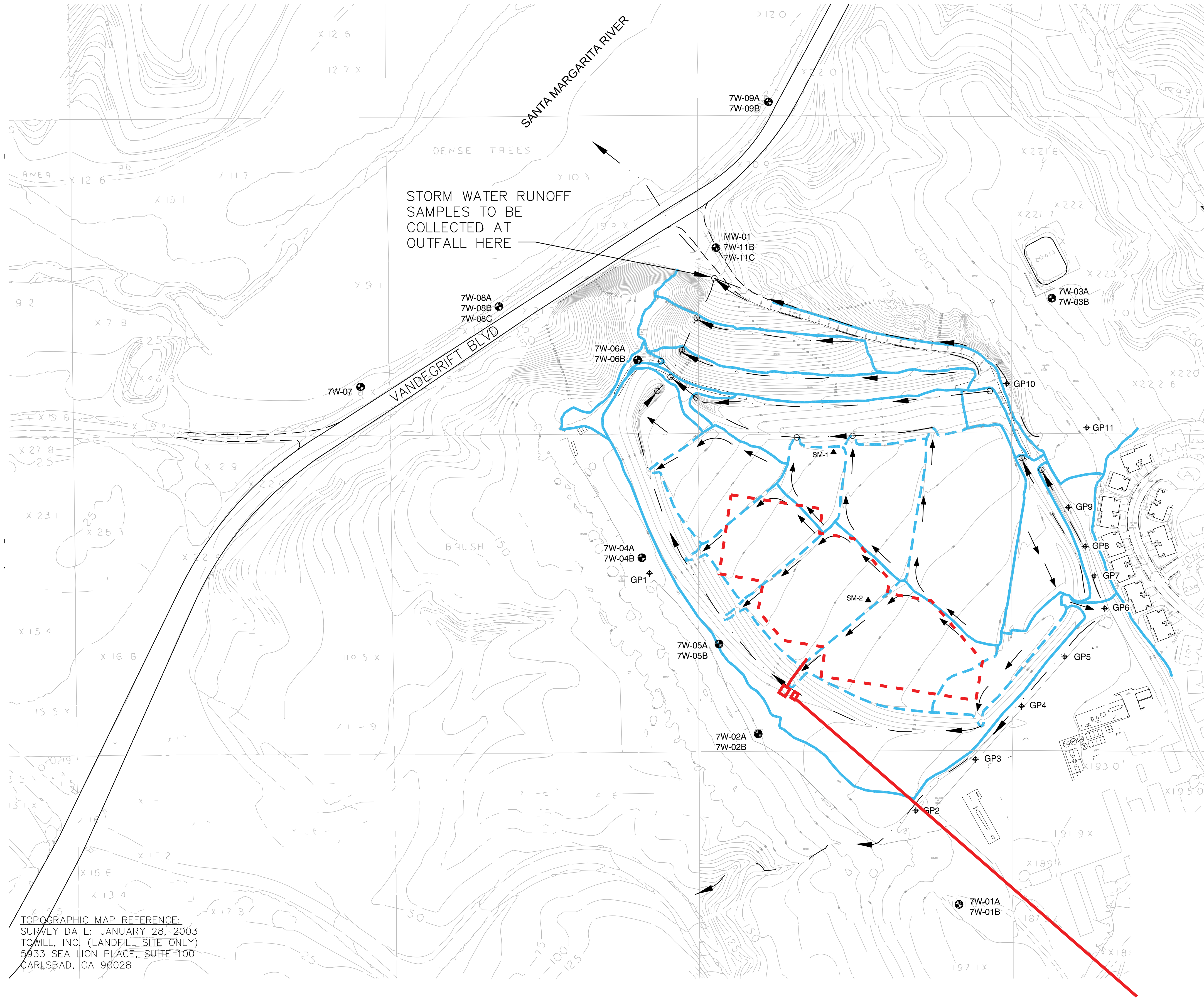


FIGURE 4
Groundwater and Gas Monitoring Well/Probe Locations and CAMU Boundaries
Design Considerations Report
Box Canyon Landfill (IR Site 7)
Marine Corps Base, Camp Pendleton, California
US Department of Navy Southwest Division
Naval Facilities Engineering Command

<u>FIGURE REFERENCE:</u>
"FINAL FIVE-YEAR REVIEW FOR OPERABLE UNITS 1 THROUGH 5, MARINE CORPS BASE, CAMP PENDLETON, CALIFORNIA"
BY NAVFACE, SOUTHWEST DIVISION
DATE: APRIL 2009

CH2MHILL



LEGEND

- Monitoring Well
- Gas Probe
- Storm Drain Inlet
- Settlement Monument
- Drainage Basin
- Drainage Sub-Basin
- Runoff Collection Ditch
- Flow Arrow
- Proposed Photovoltaic Solar Panel Array

FIGURE 5
Landfill Surface Drainage
Design Considerations Report
Box Canyon Landfill (IR Site 7)
Marine Corps Base, Camp Pendleton, California
US Department of Navy Southwest Division
Naval Facilities Engineering Command

FIGURE REFERENCE:
"FINAL REVISED POSTCLOSURE MONITORING AND MAINTENANCE PLAN IR SITE 7 BOX CANYON LANDFILL"
BY NAVFAC, SOUTHWEST DIVISION
DATE: OCTOBER 24, 2008

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CH2MHILL

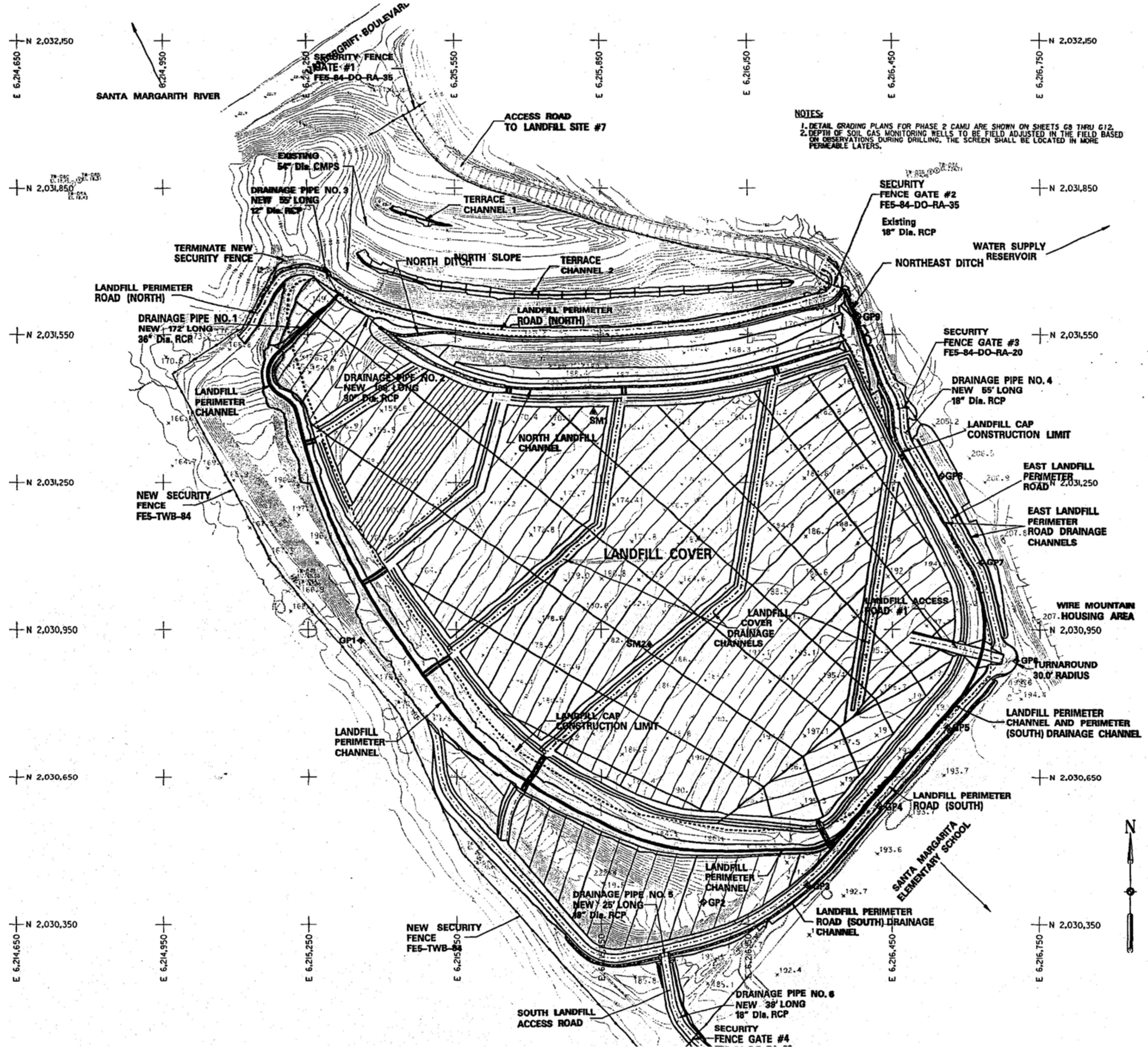


FIGURE 6
Landfill Cover Grading and Drainage Plan
Design Considerations Report
Box Canyon Landfill (IR Site 7)
Marine Corps Base, Camp Pendleton, California
US Department of Navy Southwest Division
Naval Facilities Engineering Command

FIGURE REFERENCE:
"REVISED DRAFT FINAL REMEDIAL DESIGN, IR SITE 7, BOX CANYON LANDFILL"
DATE: JULY 23, 2001

SCO390401.TS.DB landfill_plan.ai 7/09

CH2MHILL

DATE	1/3/2002	7/23/2002	12/12/2002	6/10/2003
ELEVATION	179.97	179.90	179.88	179.85

DATE	1/3/2002	7/23/2002	12/12/2002	6/10/2003
ELEVATION	191.82	191.77	191.76	191.74

LEGEND:

SM-1 ▲ SETTLEMENT MONUMENT LOCATION

HV-800 △ SURVEY CONTROL POINT

6-FT. HIGH CHAIN LINK FENCE

TOPOGRAPHIC MAP REFERENCE:
SURVEY DATE: JANUARY 28, 2003
TOWILL, INC.
5933 SEA LION PLACE, SUITE 100
CARLSBAD, CA 90028

POINT NO.	NORTHING	EASTING	ELEVATION	D NORTH	D EAST	D ELEV.
800	2031662.92	6216511.74	211.85	−0.41	−0.28	0.00
801	2031158.71	6216793.64	207.78	−0.42	−0.28	0.00
802	2030277.58	6216171.20	191.61	−0.42	−0.28	0.00
803	2030496.40	6215593.77	175.08	−0.42	−0.28	0.00
804	2031058.04	6215219.85	166.19	−0.42	−0.28	0.00
805	2031776.89	6215222.69	182.61	−0.41	−0.28	0.00
806	2031689.70	6215219.59	163.41	−0.42	−0.28	0.00

HORIZONTAL CONTROL BASED ON NAD83, ZONE 6 DATUM
VERTICAL CONTROL BASED ON NAVD88 DATUM

FIGURE REFERENCE:
"FINAL REVISED POSTCLOSURE MONITORING
AND MAINTENANCE PLAN IR SITE 7 BOX CANYON LANDFILL"
BY NAVFAC, SOUTHWEST DIVISION
DATE: OCTOBER 24, 2008

FIGURE 7
Settlement Monument Locations,
Survey Control Points, and Fence Location Map
Design Considerations Report
Box Canyon Landfill (IR Site 7)
Marine Corps Base, Camp Pendleton, California
US Department of Navy Southwest Division
Naval Facilities Engineering Command

SCO390401.TS.DB settlement_monument.ai 7/09

CH2MHILL

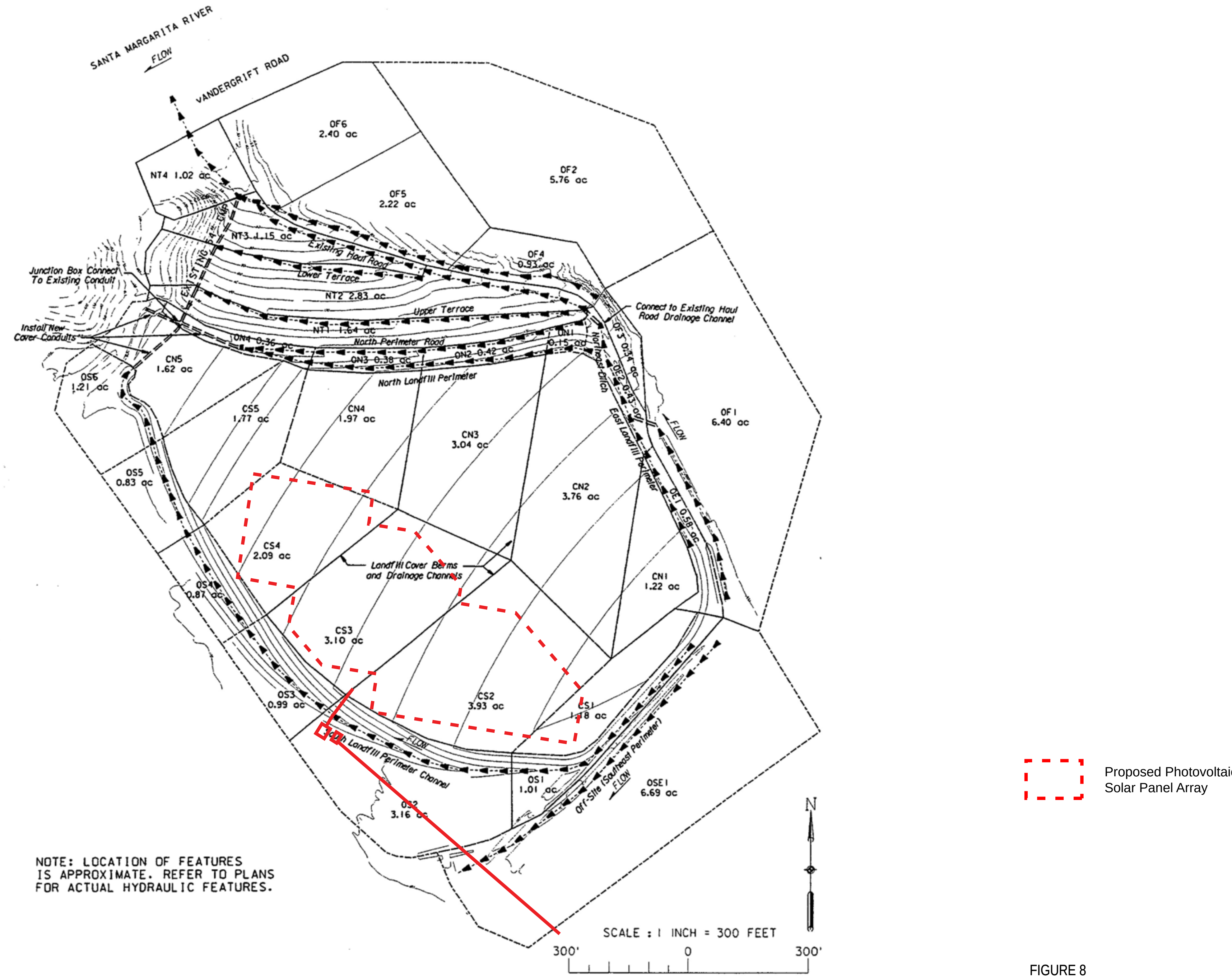


FIGURE 8
Drainage Areas
Design Considerations Report
Box Canyon Landfill (IR Site 7)
Marine Corps Base, Camp Pendleton, California
US Department of Navy Southwest Division
Naval Facilities Engineering Command

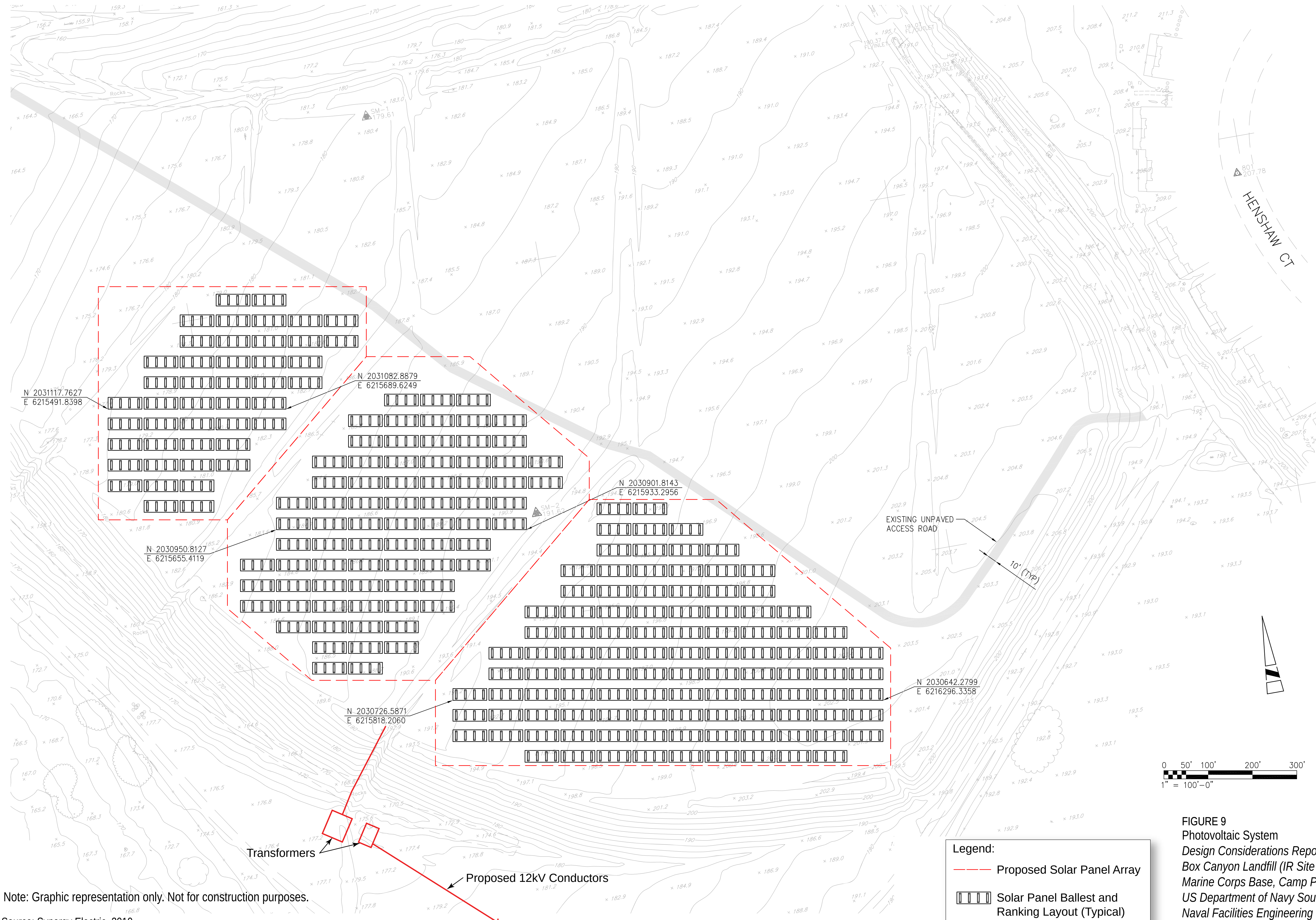


FIGURE 9
Photovoltaic System
Design Considerations Report
Box Canyon Landfill (IR Site 7)
Marine Corps Base, Camp Pendleton, California
US Department of Navy Southwest Division
Naval Facilities Engineering Command

Note: Graphic representation only. Not for construction purposes.

Source: Synergy Electric, 2010

APPENDIX A

Basis of Design Box Canyon PV System (AECOM, 2010)

BASIS OF DESIGN
Box Canyon PV System

Final Submittal

Prepared For:

Naval Facilities Engineering Command and

Marine Corps Base Camp Pendleton

Prepared By:

Engineering Partners and

AECOM

May 20, 2010

Revised for ESD
June 4, 2010

THE ENGINEERING PARTNERS, INC.
9565 WAPLES STREET, SUITE 100
SAN DIEGO, CA 92121
(858) 824-1761

Synergy Electric
"Working Together"

AECOM

Table of Contents

Box Canyon PV System
System Description & Energy Output

Installation of a solar photovoltaic (PV) array in this location is challenging due to the requirement to avoid penetrating the landfill cover and altering its intended purpose while maximizing the power production from the site. Our proposed solution meets these challenges while at the same time fulfilling the requirement for total installed capacity and annual production.

The design approach is to cover the landfill site as designated with rows of ground mounted solar array building blocks. Each solar array building block or panel is made up of 28 PV modules, equally divided and wired into two (2) strings of fourteen (14). In total, the PV system will consist of 225 solar array panels, each with a capacity of nearly 6.6 kW. Altogether, the PV array will be comprised of 6,300 high quality Sharp 235 Watt PV modules with a total system generating capacity of approximately 1.48 MW DC. The solar PV array will utilize robust racking systems for each solar building block to ensure reliable production over the system's full life. The racking systems are self-ballasted, have a 15˚ fixed tilt structure, and are oriented to the southwest at an azimuth angle of 190°. The balance of system includes Xantrex GT Series inverters and a Fat Spaniel Technologies Solar Plant Vision data acquisition system (DAS) complete with a weather station.

In order to avoid penetrating the landfill membrane, the self-ballasting will be achieved by anchoring the racking system into concrete beams placed on top of the existing ground. The methodology of the self-ballasting panel racking system on a landfill is a proven success with several megawatts currently installed and in operation.

A ground support system that does not penetrate the groundcover will require that all of the wind load must be resisted by the ballast weight of concrete foundations bearing on grade. The foundations need to be held from displacement without any kind of soil anchors or keyways, as this would compromise the landfill cover. These foundations will also be subject to the intrinsic settlement of the landfill material, which is usually predicted by the type, thickness and age of the waste fill. Differential settlement of many inches to a few feet may occur over the design life, and the design must withstand that. In this case, since the landfill was closed in 1984, with differential settlements not expected to exceed half the total settlement value, the design easily accommodates the expected settlement and has a considerable additional margin.

Versus a traditional permanently mounted ground array, the racking system is adjustable to accommodate the range of differential settlement from each corner of the foundation. The modular panel building block design allows for maximum flexibility to accommodate settlement.

Erosion concerns are addressed by the spacing of modules in the panel structures. A one inch gap is included between modules to minimize the volume of runoff along one edge. Additionally, the high efficiency Sharp PV modules reduce the number of panels required to meet the installed capacity target, which in turn minimizes the resulting runoff and erosion.

To estimate the expected PV system annual output, PVSyst version 5.06, an internationally recognized solar PV software tool has been used to model the 1.48 MW PV array system proposed. Statistical TMY3 weather data including irradiance information for the region was developed by the National Renewable Energy Laboratory (NREL) and utilized for the simulation. It is estimated that a system of this size can produce approximately 2,389 MWh in its first year. See the following PVSyst output report for simulation details including major system components; estimated monthly and annual energy outputs; and the estimated system loss diagram. It should be clarified that the PVSyst software references south with an azimuth angle of 0°, not 180°. To model the proposed array orientation correctly relative to north, an azimuth angle of 10° in the simulation parameter represents the actual array azimuth angle of 190°.

Grid-Connected System: Simulation parameters

Project :	**Camp Pendleton**			
Geographical Site	**Camp Pendleton Mcas**		**Country**	**USA**
Situation	Latitude	33.3°N	Longitude	117.4°W
Time defined as	Legal Time	Time zone UT+8	Altitude	23 m
	Albedo	0.20		
Meteo data :	Camp Pendleton Mcas, NREL TMY3			

Simulation variant :	**190 Orientation**			
	Simulation date	28/01/10 14h45		

Simulation parameters

Collector Plane Orientation	Tilt	15°	Azimuth	10°
Horizon	Free Horizon			
Near Shadings	No Shadings			

PV Array Characteristics

PV module Si-mono	Model	**NU-U235F1**		
	Manufacturer	Sharp		
Number of PV modules	In series	14 modules	In parallel	450 strings
Total number of PV modules	Nb. modules	6300	Unit Nom. Power	235 Wp
Array global power	Nominal (STC)	**1481 kWp**	At operating cond.	1294 kWp (50°C)
Array operating characteristics (50°C)	U mpp	364 V	I mpp	3557 A
Total area	Module area	**10270 m²**		

Inverter	Model	**GT 500-480**		
	Manufacturer	Xantrex		
Characteristics	Operating Voltage	300-600 V	Unit Nom. Power	500 kW AC
Inverter pack	Number of Inverter	3 units	Total Power	1500 kW AC

PV Array loss factors

Thermal Loss factor	Uc (const)	29.0 W/m²K	Uv (wind)	0.0 W/m²K / m/s
=> Nominal Oper. Coll. Temp. (G=800 W/m², Tamb=20°C, Wind velocity = 1m/s.)			NOCT	45 °C
Wiring Ohmic Loss	Global array res.	1.8 mOhm	Loss Fraction	1.5 % at STC
Serie Diode Loss	Voltage Drop	0.7 V	Loss Fraction	0.2 % at STC
Module Quality Loss			Loss Fraction	2.5 %
Module Mismatch Losses			Loss Fraction	2.0 % at MPP
Incidence effect, ASHRAE parametrization	IAM =	1 - bo (1/cos i - 1)	bo Parameter	0.05

User's needs : Unlimited load (grid)

Camp Pendleton - 190 Degree Azimuth Orientation Analysis

Grid-Connected System: Main results

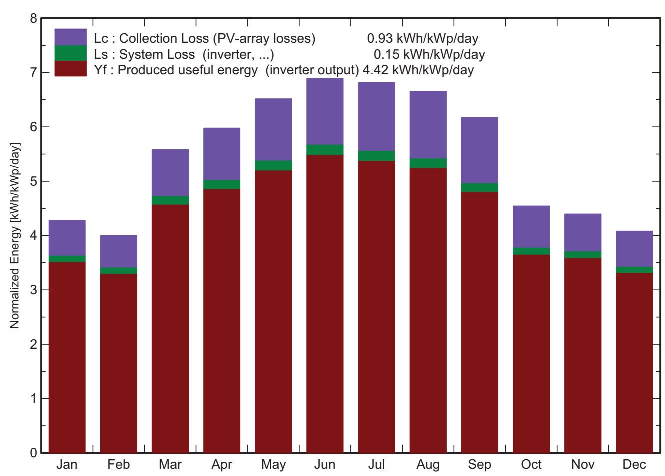
Project : **Camp Pendleton**

Simulation variant : **190 Orientation**

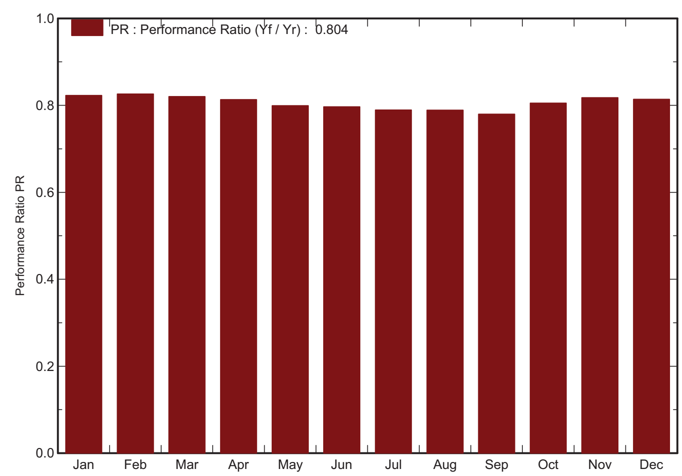
Main system parameters	System type	**Grid-Connected**		
PV Field Orientation	tilt	15°	azimuth	10°
PV modules	Model	NU-U235F1	Pnom	235 Wp
PV Array	Nb. of modules	6300	Pnom total	**1481 kWp**
Inverter	Model	GT 500-480	Pnom	500 kW ac
Inverter pack	Nb. of units	3.0	Pnom total	**1500 kW ac**
User's needs	Unlimited load (grid)			

Main simulation results				
System Production	**Produced Energy**	**2389 MWh/year**	Specific prod.	1614 kWh/kWp/year
	Performance Ratio PR	80.4 %		
Investment	Global incl. taxes	9266500 US$	Specific	6.26 US$/Wp
Yearly cost	Annuities (Loan 5.0%, 20 years)	743568 US$/yr	Running Costs	0 US$/yr
Energy cost		**0.31 US$/kWh**		

Normalized productions (per installed kWp): Nominal power 1481 kWp



Performance Ratio PR



190 Orientation

Balances and main results

	GlobHor	T Amb	GlobInc	GlobEff	EArray	E_Grid	EffArrR	EffSysR
	kWh/m²	°C	kWh/m²	kWh/m²	kWh	kWh	%	%
January	102.8	11.45	132.7	127.9	167068	161649	12.26	11.86
February	95.5	11.92	111.9	108.1	141802	136948	12.33	11.91
March	155.5	13.11	173.0	167.9	217367	210083	12.24	11.83
April	172.4	13.96	179.3	174.4	223439	215995	12.13	11.73
May	201.8	17.46	202.0	196.3	247358	239035	11.92	11.52
June	209.6	18.12	206.8	201.2	252378	243889	11.89	11.49
July	212.8	20.16	211.3	205.5	255530	246954	11.78	11.38
August	199.9	19.70	206.3	201.0	249148	240995	11.76	11.38
September	169.9	20.52	185.1	180.1	220894	213694	11.62	11.24
October	122.1	16.60	140.8	136.5	173721	167863	12.01	11.61
November	103.9	12.06	131.9	127.3	165142	159633	12.19	11.79
December	94.9	12.32	126.5	121.6	157710	152444	12.14	11.73
Year	1841.1	15.64	2007.6	1947.8	2471557	2389183	11.99	11.59

Legends:
- GlobHor: Horizontal global irradiation
- T Amb: Ambient Temperature
- GlobInc: Global incident in coll. plane
- GlobEff: Effective Global, corr. for IAM and shadings
- EArray: Effective energy at the output of the array
- E_Grid: Energy injected into grid
- EffArrR: Effic. Eout array / rough area
- EffSysR: Effic. Eout system / rough area

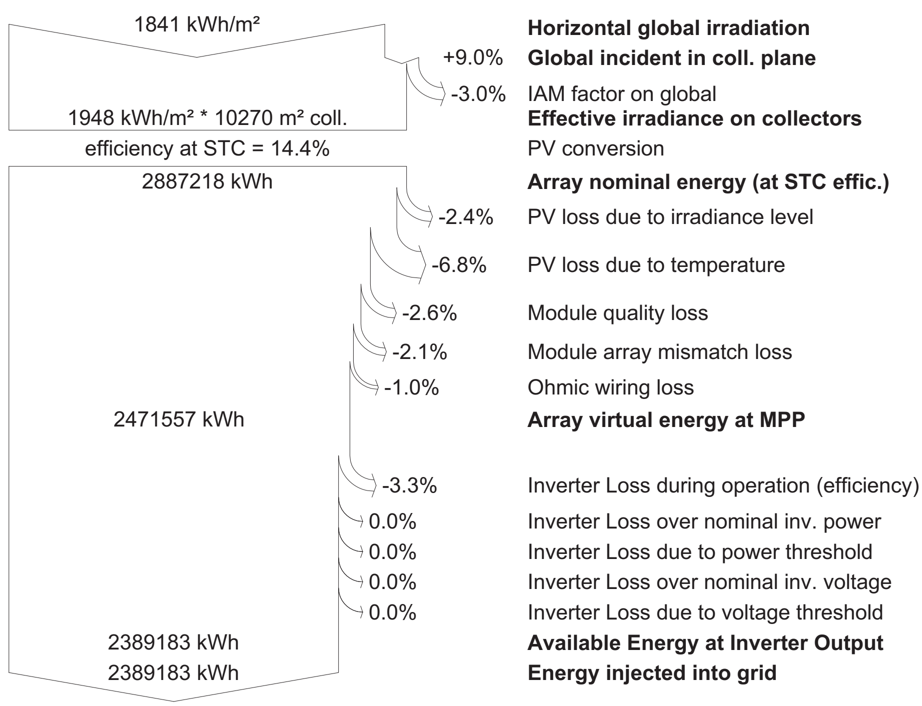
Grid-Connected System: Loss diagramEconomic evaluation

Project : **Camp Pendleton**

Simulation variant : **190 Orientation**

Main system parameters	System type	**Grid-Connected**		
PV Field Orientation	tilt	15°	azimuth	10°
PV modules	Model	NU-U235F1	Pnom	235 Wp
PV Array	Nb. of modules	6300	Pnom total	**1481 kWp**
Inverter	Model	GT 500-480	Pnom	500 kW ac
Inverter pack	Nb. of units	3.0	Pnom total	**1500 kW ac**
User's needs	Unlimited load (grid)			

Loss diagram over the whole year



Basis of Design for Box Canyon PV System

CIVIL

Prepared For:

Naval Facilities Engineering Command and

Marine Corps Base Camp Pendleton

Prepared By:

AECOM

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Synergy Electric
"Working Together"

AECOM

System Summary

CIVIL SYSTEM SUMMARY

Site Details		
Site Location	Marine Corps Base Camp Pendleton	
Site Description	Box Canyon Landfill	
Site Latitude	33.2° N	
Item	**Value**	**Justification**
Hydrology	County of San Diego	
Ballast Support	Gravel/Rock	No penetration of ET cover
Re-vegetation	Per approved materials list	Drought resistant, shade tolerant, can withstand some disturbance
Horizontal Control	NAD 83 Coordinates	Based on existing survey monuments

Basis of Design

1. County of San Diego Hydrology Manual
2. Vegetation per approved materials list from section 2.4 of the preliminary report dated August 17, 2009.
3. NAD 83 coordinate system and use of existing survey control monuments.

Calculations

See attached hydrology calculations.

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Memorandum

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DOMENIC J. LUPO
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Exp. 12/31/11
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STATE OF CALIFORNIA

To	Annika Moman	Page	1
CC			
Subject	Photovoltaic System – Marine Corps Base Camp Pendleton, CA		
From	Domenic Lupo		
Date	March 29, 2010		

Per the scope of work AECOM Transportation has prepared this memorandum regarding the drainage calculations based on the 100% design. We agreed to provide calculations based on the 100% design including 1) overland flow time of concentration, 2) erosion potential, 3) drainage ditch flow rate, 4) drainage ditch velocity, 5) Panel Drip Lines, 6) C factor, 7) Time of Concentration, 8) Intensity, and 9) Flow Rate (Q). In addition to those items we have also considered surface impact from the rack drip-lines. We have provided a spreadsheet attachment showing our calculations for the 100% design.

1) **Overland Flow Time of Concentration:** Three factors contribute to overland flow time of concentration: watercourse distance, site slope/gradient, and runoff coefficient. Comparing these three factors from the existing condition and the proposed design will show if the overland flow time of concentration would increase or decrease based on the proposed design. The watercourse distance and site slope/gradient remain unchanged from the existing to the proposed condition based on the panel layout. The runoff coefficient increases in the proposed condition, however this does not affect the time of concentration. It will affect the runoff volume, but since the longest path of travel for the runoff remains the same and is across the same terrain, the overland flow time of concentration remains unchanged.

2) **Erosion Potential:** Erosion potential is examined by using the Universal Soil Loss Equation. This equation is based on a number of factors including rainfall erosion index, soil erodibility factor, slope length and slope gradient factor, vegetation factor, and erosion control practice factor. Since the proposed design includes parameters to protect these factors, each of them will remain the same when comparing the existing condition to the proposed design. The estimated a soil loss of roughly 0.52 tons per acre per year is well under the maximum allowable of 2 tons per acre per year by the EPA.

3) **Drainage Ditch Flow Rate:** The maximum flow rate the ditches can carry is 11 cfs. The existing condition calculation showed none of the basins would exceed this amount after the panels were constructed. The proposed design proposes a layout of the panels and our calculations show that none of the affect areas of the proposed layout will result in a flow rate above 11 cfs. The largest flow rate for the affected areas is 5.40 cfs, well below the acceptable limit.

4) **Drainage Ditch Velocity:** Three main factors contribute to drainage ditch velocity: channel shape/type, flow rate, and channel slope. The proposed design will only change one of those factors, flow rate. Since the proposed design will generate flow rates in the ditches that are much lower than the maximum allowable flow rate of 11 cfs, the drainage ditch velocity associated with the studied flows is acceptable.

5) **Runoff from Panel Drip Lines:** There will be 4 horizontal drip lines from each rack with ¼ of the panel area contributing to each line. That equates to roughly 130 sf of panel area resulting in less than 0.01 cfs per drip line. This amount of water is evenly spread out over the 38 foot long drip line resulting in a negligible impact to the surface below therefore no surface treatment is required beyond re-vegetation.

6) **C Factor:** C Factors are assigned by the County of San Diego Hydrology Manual (CSDHM) based on the imperviousness of the surface in which the rainfall lands. The CSDHM has assigned the existing condition a C factor or 0.25 and we have assigned the panels a C factor of 1.0 since they are completely impervious. Comparing the relative areas of these two surfaces is how we determined a blended C factor.

7) **Time of Concentration:** The CSDHM includes a graph and formula to determine the Time of Concentration (Tc) based on the overland length of flow of the longest drainage path in any basin, the slope of the land, and the C factor. That path was calculated to be 425' and the resulting Tc was 17.5 minutes.

8) **Intensity:** the CSDHM includes a formula to determine the Intensity (I) to be used for each site. The I factor is based on historical rainfall data within the County. Isopluvial maps are used by the County in conjunction with the Tc to determine the I. For this site the I value is 2.94 inches/hour.

9) **Flow Rate (Q):** The flow rate is calculated by multiplying the C factor by the Intensity by the Area (acres) resulting in cubic feet per second.

Summary: Per the above noted items, the drainage characteristics of the site will remain mostly the same comparing the existing to the proposed conditions. The one important change is the amount of runoff. By placing impervious solar panels on the site this increases the runoff by decreasing the pervious area. The net result is an increased amount of water to the drainage ditches. Since there is additional runoff to the drainage ditches the result is there is less water infiltrating the ground. The amount of increased water to the ditches is equal to the amount of reduced infiltration. Please see the attached calculations spreadsheet and associated maps, charts, & graphs for the detailed basin calculations.

Drainage Calculations
Photovoltaic System - Marine Corps Base Camp Pendleton, CA
AECOM Transportation - San Diego, CA
March 29, 2010

Givens/Assumptions:

Drainage Analysis based on the County of San Diego Hydrology Manual for a 100-year storm event
Q = C*I*A ===> Maximum Q for channels is 11cfs
C (Blended) = Runoff coefficent for each area (panel area=1.0, landfill cover area=0.25)
I = 2.94
A = Area of the Basin
T=17.5 minutes (time of concentration based on longest drainage path being 425')
Soil Type is Type is B according to the geotechnical report
See attached for drainage basin map, C factor table, Time of Concentration Chart, & Intesity Chart

Area Drainage for the 100 year Storm

			Existing Condition					Proposed Condition						
Basin Name	Total Area (Ac)	Panel Area (Ac)	C (Blended)	Slope (%)	T (min)	I (in/hr)	Q (cfs)	C (Blended)	Slope (%)	T (min)	I (in/hr)	Q (cfs)	Less than 11 cfs?	Increase (cfs)
CS1	1.18	0.12	0.25	3.0%	17.5	2.94	0.87	0.33	3.0%	17.5	2.94	1.13	TRUE	0.26
CS2	3.93	1.14	0.25	3.0%	17.5	2.94	2.89	0.47	3.0%	17.5	2.94	5.40	TRUE	2.51
CS3	3.10	0.90	0.25	3.0%	17.5	2.94	2.28	0.47	3.0%	17.5	2.94	4.26	TRUE	1.98
CS4	2.09	0.54	0.25	3.0%	17.5	2.94	1.54	0.44	3.0%	17.5	2.94	2.73	TRUE	1.19
CN2	3.76	0.00	0.25	3.0%	17.5	2.94	2.76	0.25	3.0%	17.5	2.94	2.76	TRUE	0.00
CN3	3.04	0.00	0.25	3.0%	17.5	2.94	2.23	0.25	3.0%	17.5	2.94	2.23	TRUE	0.00

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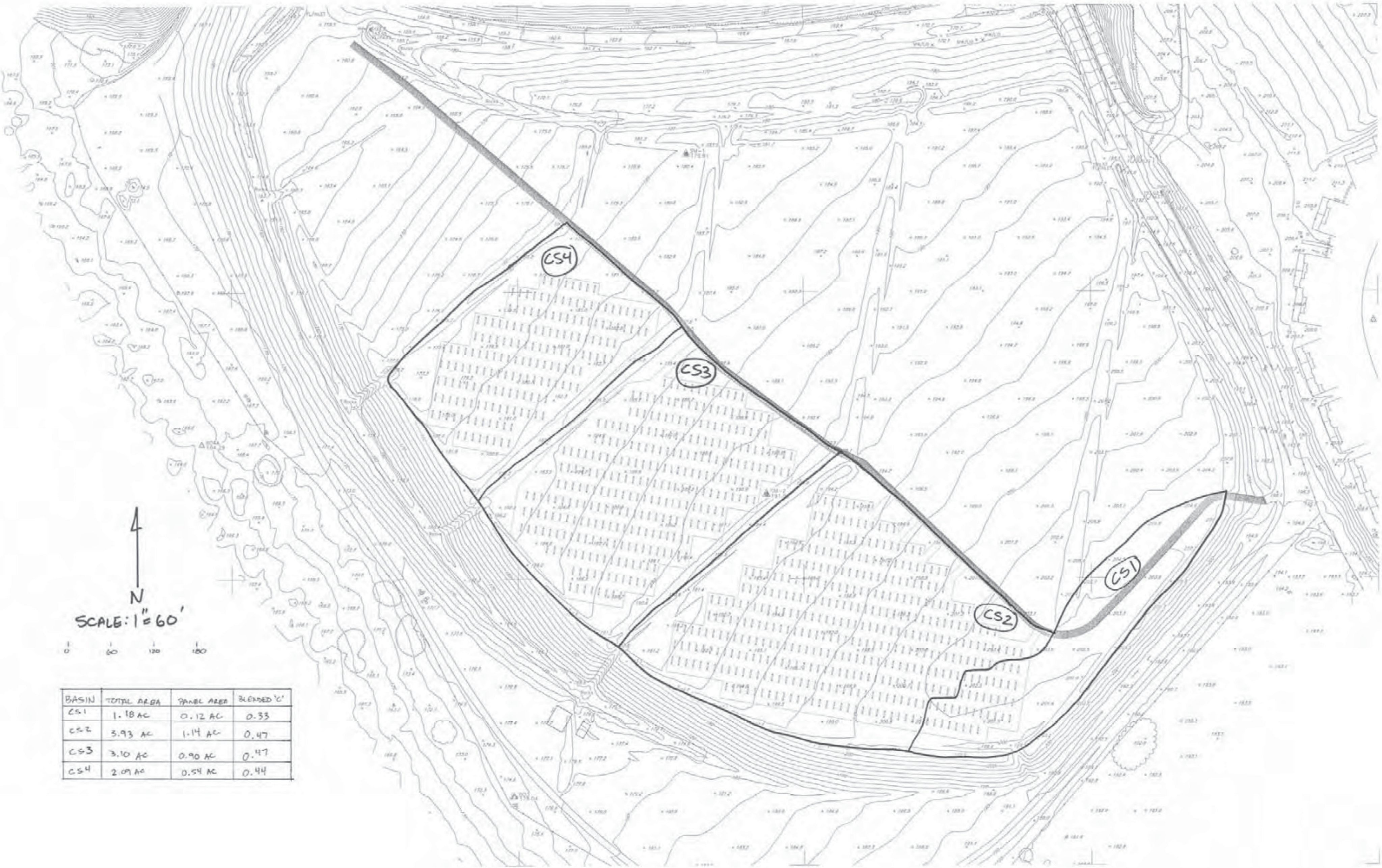


BASIN	TOTAL AREA	PANEL AREA	BLENDED 'C'
CS1	1.18 AC	0.12 AC	0.33
CS2	3.93 AC	1.14 AC	0.47
CS3	3.10 AC	0.90 AC	0.47
CS4	2.09 AC	0.54 AC	0.44

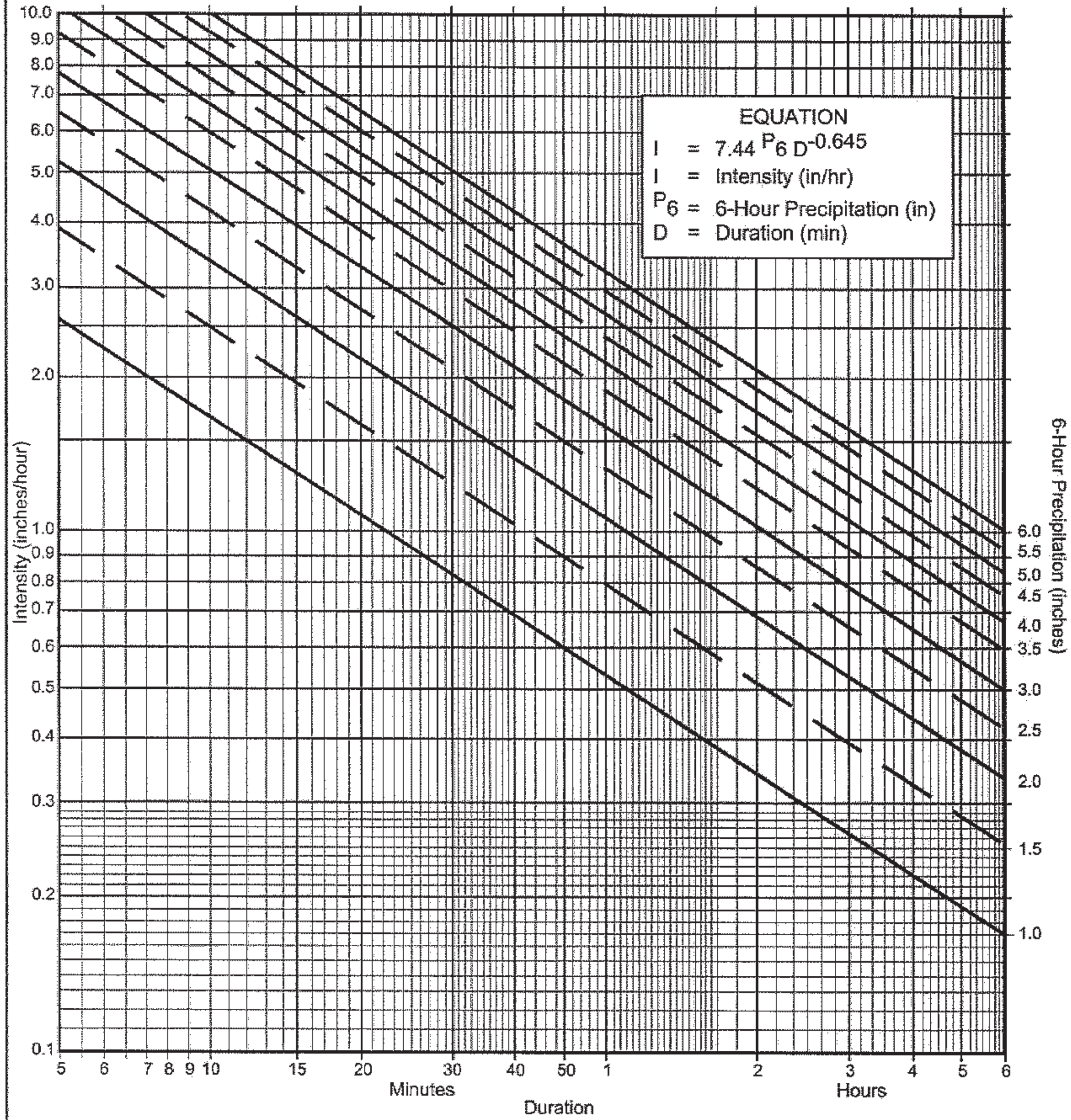
Table 3-1
RUNOFF COEFFICIENTS FOR URBAN AREAS

Land Use		Runoff Coefficient "C"				
			Soil Type			
NRCS Elements	County Elements	% IMPER.	A	B	C	D
Undisturbed Natural Terrain (Natural)	Permanent Open Space	0*	0.20	* 0.25	0.30	0.35
Low Density Residential (LDR)	Residential, 1.0 DU/A or less	10	0.27	0.32	0.36	0.41
Low Density Residential (LDR)	Residential, 2.0 DU/A or less	20	0.34	0.38	0.42	0.46
Low Density Residential (LDR)	Residential, 2.9 DU/A or less	25	0.38	0.41	0.45	0.49
Medium Density Residential (MDR)	Residential, 4.3 DU/A or less	30	0.41	0.45	0.48	0.52
Medium Density Residential (MDR)	Residential, 7.3 DU/A or less	40	0.48	0.51	0.54	0.57
Medium Density Residential (MDR)	Residential, 10.9 DU/A or less	45	0.52	0.54	0.57	0.60
Medium Density Residential (MDR)	Residential, 14.5 DU/A or less	50	0.55	0.58	0.60	0.63
High Density Residential (HDR)	Residential, 24.0 DU/A or less	65	0.66	0.67	0.69	0.71
High Density Residential (HDR)	Residential, 43.0 DU/A or less	80	0.76	0.77	0.78	0.79
Commercial/Industrial (N. Com)	Neighborhood Commercial	80	0.76	0.77	0.78	0.79
Commercial/Industrial (G. Com)	General Commercial	85	0.80	0.80	0.81	0.82
Commercial/Industrial (O.P. Com)	Office Professional/Commercial	90	0.83	0.84	0.84	0.85
Commercial/Industrial (Limited I.)	Limited Industrial	90	0.83	0.84	0.84	0.85
Commercial/Industrial (General I.)	General Industrial	95	0.87	0.87	0.87	0.87

*The values associated with 0% impervious may be used for direct calculation of the runoff coefficient as described in Section 3.1.2 (representing the pervious runoff coefficient, Cp, for the soil type), or for areas that will remain undisturbed in perpetuity. Justification must be given that the area will remain natural forever (e.g., the area is located in Cleveland National Forest).

DU/A = dwelling units per acre

NRCS = National Resources Conservation Service



Directions for Application:

(1) From precipitation maps determine 6 hr and 24 hr amounts for the selected frequency. These maps are included in the County Hydrology Manual (10, 50, and 100 yr maps included in the Design and Procedure Manual).

(2) Adjust 6 hr precipitation (if necessary) so that it is within the range of 45% to 65% of the 24 hr precipitation (not applicaple to Desert).

(3) Plot 6 hr precipitation on the right side of the chart.

(4) Draw a line through the point parallel to the plotted lines.

(5) This line is the intensity-duration curve for the location being analyzed.

Application Form:

(a) Selected frequency 100 year

(b) P_6 = 2.5 in., P_{24} = 4.5, $\frac{P_6}{P_{24}}$ = 55.5 %(2)

(c) Adjusted $P_6^{(2)}$ = 2.5 in.

(d) t_x = 17.5 min.

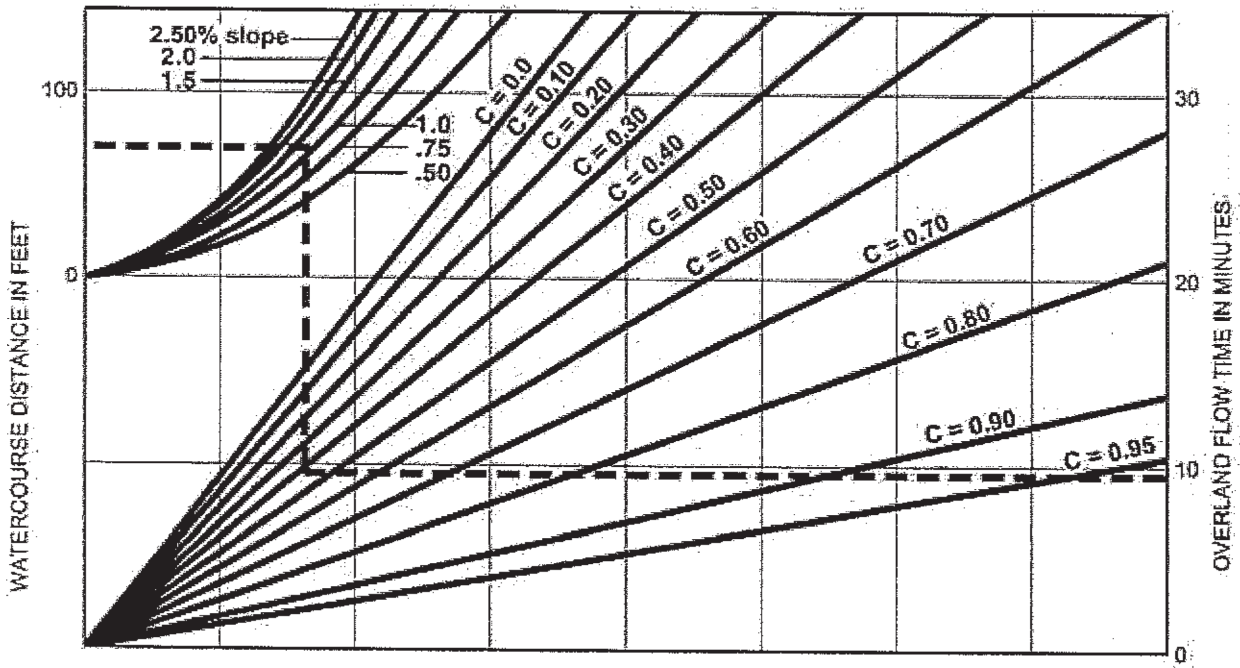
(e) I = 2.94 in./hr.

Note: This chart replaces the Intensity-Duration-Frequency curves used since 1965.

P6	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6
Duration	I	I	I	I	I	I	I	I	I	I	I
5	2.63	3.95	5.27	6.59	7.90	9.22	10.54	11.86	13.17	14.49	15.81
7	2.12	3.18	4.24	5.30	6.36	7.42	8.48	9.54	10.60	11.66	12.72
10	1.68	2.53	3.37	4.21	5.05	5.90	6.74	7.58	8.42	9.27	10.11
15	1.30	1.95	2.59	3.24	3.89	4.54	5.19	5.84	6.49	7.13	7.78
20	1.08	1.62	2.15	2.69	3.23	3.77	4.31	4.85	5.39	5.93	6.46
25	0.93	1.40	1.87	2.33	2.80	3.27	3.73	4.20	4.67	5.13	5.60
30	0.83	1.24	1.66	2.07	2.49	2.90	3.32	3.73	4.15	4.56	4.98
40	0.69	1.03	1.38	1.72	2.07	2.41	2.76	3.10	3.45	3.79	4.13
50	0.60	0.90	1.19	1.49	1.79	2.09	2.39	2.69	2.98	3.28	3.58
60	0.53	0.80	1.06	1.33	1.59	1.86	2.12	2.39	2.65	2.92	3.18
90	0.41	0.61	0.82	1.02	1.23	1.43	1.63	1.84	2.04	2.25	2.45
120	0.34	0.51	0.68	0.85	1.02	1.19	1.36	1.53	1.70	1.87	2.04
150	0.29	0.44	0.59	0.73	0.88	1.03	1.18	1.32	1.47	1.62	1.76
180	0.26	0.39	0.52	0.65	0.78	0.91	1.04	1.18	1.31	1.44	1.57
240	0.22	0.33	0.43	0.54	0.65	0.76	0.87	0.98	1.08	1.19	1.30
300	0.19	0.28	0.38	0.47	0.56	0.66	0.75	0.85	0.94	1.03	1.13
360	0.17	0.25	0.33	0.42	0.50	0.58	0.67	0.75	0.84	0.92	1.00

Intensity-Duration Design Chart - Template

FIGURE **3-1**



EXAMPLE:

Given: Watercourse Distance (D) = 70 Feet
Slope (s) = 1.3%
Runoff Coefficient (C) = 0.41
Overland Flow Time (T) = 9.5 Minutes

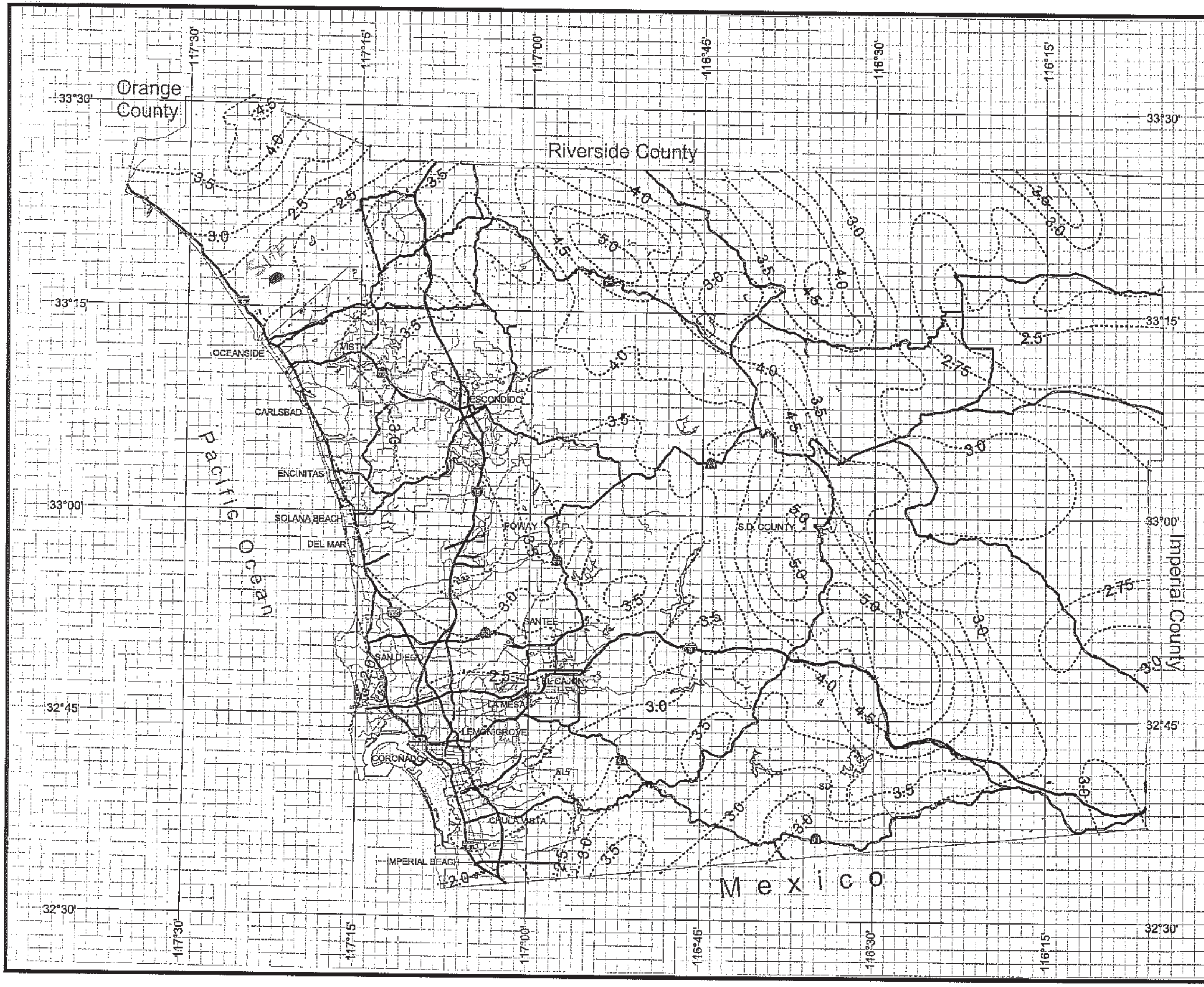
$$T = \frac{1.8\,(1.1-C)\sqrt{D}}{\sqrt[3]{s}}$$

SOURCE: Airport Drainage, Federal Aviation Administration, 1965

Rational Formula - Overland Time of Flow Nomograph

FIGURE

3-3



County of San Diego Hydrology Manual

Rainfall Isopluvials

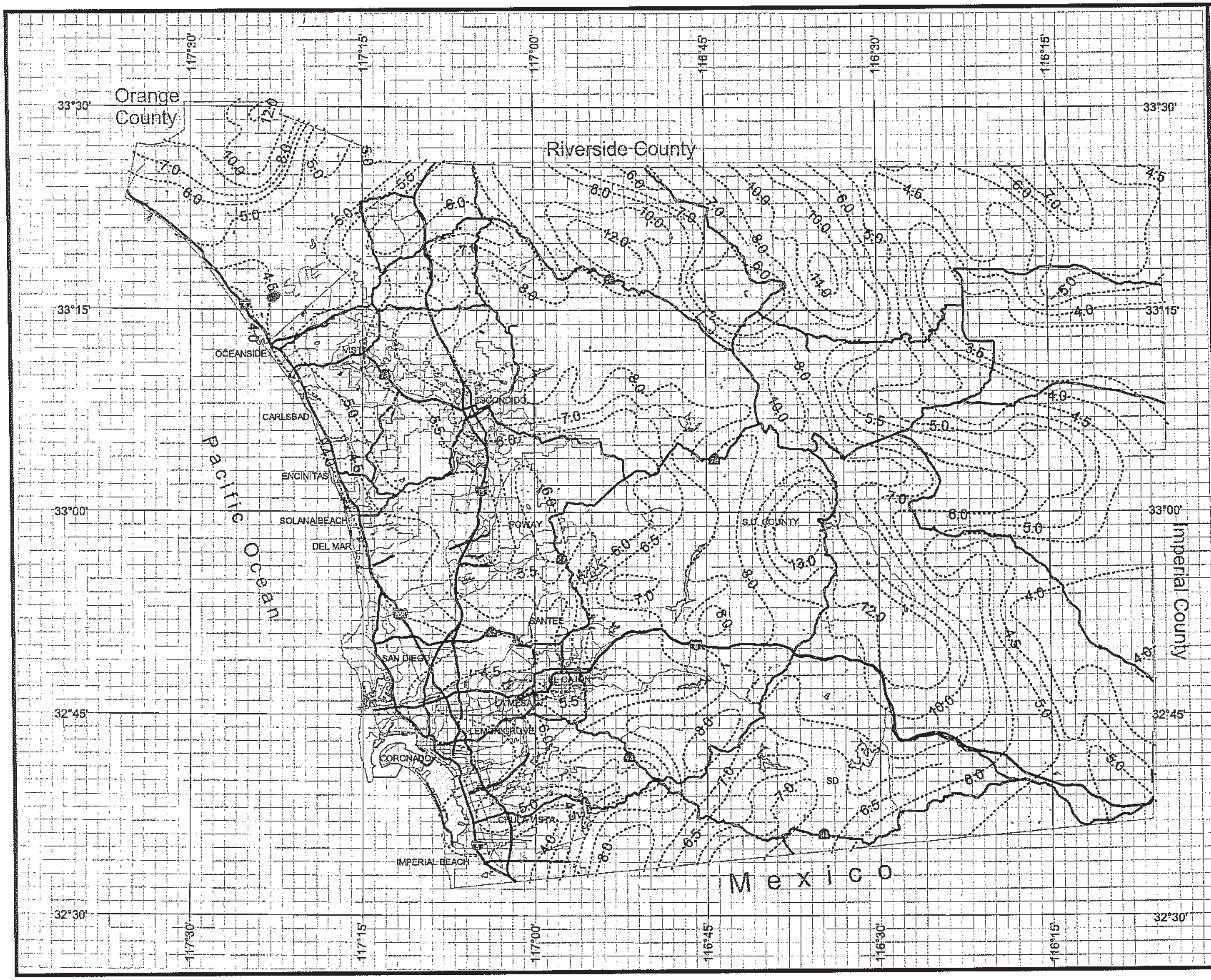
100 Year Rainfall Event - 6 Hours

-------- Isopluvial (inches)

DPW GIS

SanGIS
We Have San Diego Covered!

3 0 3 Miles



County of San Diego Hydrology Manual

Rainfall Isopluvials

100 Year Rainfall Event - 24 Hours

-------- Isopluvial (inches)

DPW GIS

Department of Public Works
Geographic Information Services

SanGIS

We Have San Diego Covered!

N
W E
S

3 0 3 Miles

Basis of Design for
Box Canyon PV System

STRUCTURAL

Prepared For:

Naval Facilities Engineering Command and

Marine Corps Base Camp Pendleton

Prepared By:

AECOM

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Synergy Electric
"Working Together"

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System Summary

STRUCTURAL SYSTEM SUMMARY

Site Details		
Site Location	Marine Corps Base Camp Pendleton	
Site Description	Box Canyon Landfill	
Site Latitude	33.2° N	
Item	**Value**	**Justification**
Racking System Model	UniRac ULA	
Racking System Design	4 leg pairs	See calculations
Module Tilt	15 degrees	
Ballast Type	Self-ballasted, pre-fab concrete	No penetration of ET cover
Soil Bearing Capacity	600 PSF	See Geotechnical BOD
Seismic Design Category	D	
Exposure Category	C	ASCE 7-05
Importance Factor	1.0 (seismic) 0.87 (wind)	ASCE 7-05
Wind Speed	85 MPH	ASCE 7-05

Basis of Design

1. UFC 1-200-01 General Building Requirements
2. Design Loads per UFC 3-310-01 Structural Load Data
3. Dead Loads based on estimated existing conditions
4. Design Wind Pressure per ASCE 7-05, Section 6.5.13.2 & Equation 6-25 for tilt angles 0-45 degrees

5. Seismic Loading

    5.1. Seismic coefficient per Table 15.4-1 ASCE 7-05

    5.2. Sliding coefficient 0.49 based on gravel base under ballast

6. Rack Design

    6.1. Front edge height 48” to accommodate native vegetation on landfill cover.

7. Ballast Design

    7.1. Designed in accordance with ACI 318-05, IBC 2006, ASCE 7-05 based on uplift forces from rack system analysis (see calculations).

    7.2. Pre-stressed steel reinforcement conforming to ASTM A-416 low relaxation grade 270, spirals to ASTM A82

Calculations

Wind loading and seismic calculations included on following pages. Calculations reviewed by structural engineer of record.

AECOM

AECOM
750 Corporate Woods Parkway
Vernon Hills, IL 60061
www.aecom.com

847 279 2500 tel
847 279-2510 fax

March 24, 2010

Ms. Annika Moman, CEM
Project Manager
AECOM
440 Stevens Avenue, Suite 250
Solana Beach, CA 92075

Ms. Momann:

AECOM has performed the following calculations:

- Bearing Capacity Analysis dated February 9, 2010
- Settlement of Individual footings dated February 9, 2010
- Global Settlement Analysis dated March 11, 2010 and March 19, 2010
- Coefficient of Sliding Between Ballast and Gravel Subgrade dated March 11, 2010
- Static Slope Stability Analysis dated March 10, 2010
- Pseudostatic Slope Stability Analysis dated March 10, 2010
- Makdisi-Seed Slope Deformation Analysis dated March 10, 2010

AECOM has reviewed the calculations prepared by UnirRac and Old Castle for general content and use in our analysis. We find their calculations in general accordance with the design criteria for this project.

Respectfully,

3-24-10
Jeremy M. Thomas, P.E.
C-73551

REGISTERED PROFESSIONAL ENGINEER
JEREMY M. THOMAS
C-73551
Exp. 12-31-10
CIVIL
STATE OF CALIFORNIA

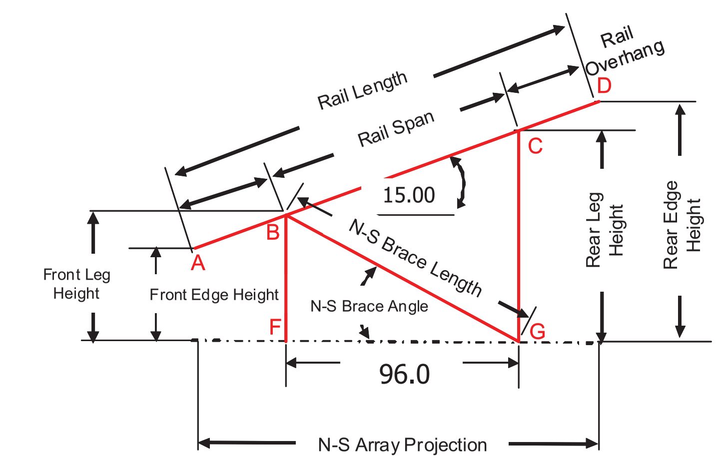
Project	SYNERGY	Quote	DRB-LA-091113-1430

Project Ident:	SYNERGY	**Customer:**	AECOM	Contact:	Andrew Agopian	Revision	4
Address1:		**Address:**	300 S. Grand Ave.	Phone:	213-330-7249	Preparer	danb
Address2:		**Address2:**	2nd Floor	Phone2:			
City, ST, Zip:	Camp Pendleton, CA 92005	**City, ST, Zip:**	Los Angeles, CA90071	Email:	andrew.agopian@aecom.com		

ULA Geometry

Complete

Module Specification				Sub-Array Configuration				ULA Totals	
Sharp - NU-235U1F				# Rows:	4	Column N-S Length (in):	161	# SubArrays:	225
N-S Dim (in):	39.1	N-S Spacing (in):	1	# Columns:	7	Array E-W Dimension (in):	452	Total Modules:	6300
E-W Dim (in):	64.6	E-W Spacing (in):	0	SubArray Modules:	28	Array N-S Projection (in):	158	ULA Power Rating (kW):	1480.5
Thickness (in):	1.8	Power Rating (W):	235	Rails Per Module:	2				
Orientation:	L	Weight (lbs):	44	Extended Rail (in):	3				



Member Description	Variables	Standard	Revised	Units
Rail Length (in):	AD	164	164	in
Tilt Angle (deg):	θ	15	15	degrees
Rail Span:	BC	98.4	99.39	in
Rail Overhang:	AB, CD	32.8	32.31	in
Front Edge Height:	AE	48	48	in
Rear Edge Height:	DH	90.45	90.45	in
Front Leg Length:	BF	56.49	56.36	in
Rear Leg Length:	CG	81.96	82.09	in
N-S Cross Brace Length:	BG	168.18	111.32	in
N-S Cross Brace Angle:	β	19.63	30.42	degrees
N-S Leg Spacing:	FG	158.41	96	in

Project SYNERGY | **Quote** DRB-LA-091113-1430

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Wind Load Calculations

Complete

Wind Load Variables

Tilt Angle (deg):	15
Array Height above ground:	7
Exposure Category:	C
Basic Wind Speed, V (mph):	85.00
Importance Factor:	0.87
Roof Zone Multiplier:	1

MWFRS Wind Load Calculation

$$q_h = 0.00256 K_z K_{zt} K_d V^2 I (lb/ft^2)$$

Adjustment Factor for height and Exposure Category	Kz:	0.85
Topographic Factor (assumed to be 1 for level ground)	Kzt:	1
Directionality Factor	Kd:	0.85
Wind Load (psf)	qh:	11.63

Maximum Loads (psf)

	Uplift		Down Force
Front Leg:	-12.85	Front Leg:	17.79
Rear Leg:	-18.78	Rear Leg:	15.82

ASCE 7-05 Open Building Unobstructed Wind Flow Coefficients, Cn

	Load Case A	Load Case B	Load Case A	Load Case B
Front Leg	-1.3	0	1.3	1.8
Rear Leg	-0.9	-1.9	1.6	0.6
Average	-1.1	-0.95	1.45	1.2

ASCE 7-05 MWFRS Open Buildings Wind Load

Gust Effect Factor (G): 0.85

$$p = q_h GCn$$

	Load Case A	Load Case B	Load Case A	Load Case B
Cn (Front Leg):	-12.85	10	12.85	17.79
Cn (Rear Leg):	-10	-18.78	15.82	10
Cn (Avg):	-10.87	-10	14.33	11.86

Project SYNERGY

Quote DRB-LA-091113-1430

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Combination Load Analysis

Complete

Load Combination Variable (psf)

Dead Load:	6.76	Assumed
Snow Load:	0	

Max Load Results (psf)

	Down Force	Uplift
Front Leg:	24.79	-8.65
Rear Leg:	22.82	-14.58
Max (Absolute):	22.82	

Load Combination Factors

	Dead Load	Snow Load	Wind Load
Load Case 1 (downforce):	1	1	0
Load Case 2 (downforce):	1	0	1
Load Case 3 (downforce):	1	0.75	0.75
Load Case 4 (uplift):	0.6		1

Front Leg Load Combinations (psf)

	Wind Load Case A	Wind Load Case B
Load Case 1 (downforce):	7	7
Load Case 2 (downforce):	19.85	24.79
Load Case 3 (downforce):	16.64	20.34
Max Downforce:	19.85	24.79
Load Case 4 (uplift):	-8.65	14.2

Rear Leg Load Combinations (psf)

	Wind Load Case A	Wind Load Case B
Load Case 1 (downforce):	7	7
Load Case 2 (downforce):	22.82	17
Load Case 3 (downforce):	18.87	14.5
Max Downforce:	22.82	17
Load Case 4 (uplift):	-5.8	-14.58

Project SYNERGY — Quote DRB-LA-091113-1430

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Horizontal Pipe Design

Complete

Pipe Design Inputs

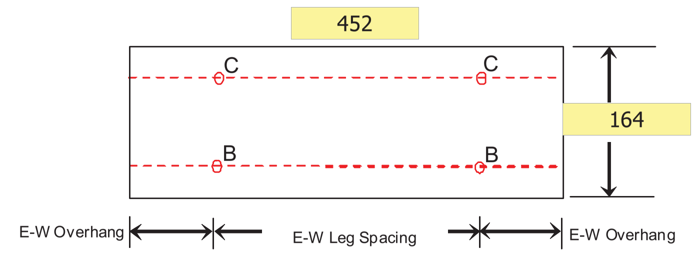
Pipe Span (E-W Leg Spacing):	123
Number of Leg Pairs:	4
Horizontal Pipe Overhang (in):	41.1

0

Pipe Design Loads (psf)

Front Leg (psf):	24.79
Rear Leg (psf):	22.82

Maximum absolute value of Load Combination Loads



Pipe Material Specifications

Pipe Selection: 3 in.Schedule 40

Modulus of Elasticity, E (psf):	4.18E+09
Moment of Intertia, I (ft^4):	0.000137
Section Modulus, Z (ft^3):	0.00127
Yield Stress, Fy (psf):	5040000
Array Width (in):	452
Rail Length (in):	164

Description	Front Horizontal Pipe		Rear Horizontal Pipe	
	Max	Revised	Max	Revised
Max Distributed Load (plf):	166.3	166.3	153.08	153.08
Pipe Span (in):	162.94	123.27	162.94	123.27
Allowable Bending Moment (lb-ft):	3832.81	3832.81	3832.81	3832.81
Actual Bending Moment (lb-ft):	3832.62	2193.59	3527.94	2019.21
Actual/Allowable Moment:	100%	57%	92%	53%
Allowable Total Deflection L/70 (in):	2.33	1.76	2.33	1.76
Actual Deflection (in):	1.54	0.51	1.42	0.47
Actual/Allowable Deflection:	66%	29%	61%	27%

Project	SYNERGY	Quote	DRB-LA-091113-1430

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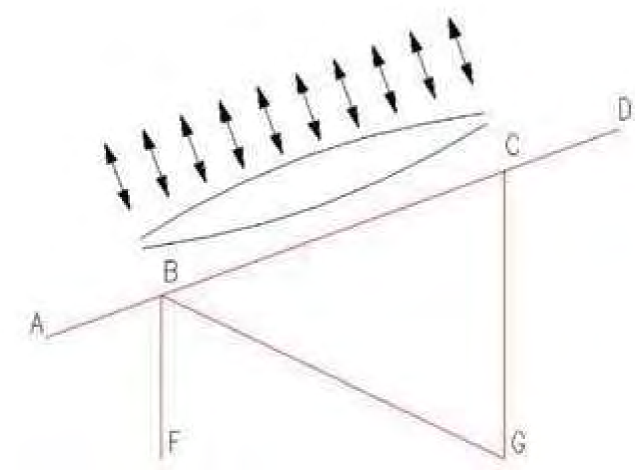
Rail Bending

Complete

Rail Design Variables	
Rail Length (in):	164
Rail Overhang (in):	32.31
Rail Span (in):	99.39

Rail Distributed Load Calculation	
Maximum Average Design Load (psf):	21.33
Module Dim Perpendicular to Rails (in):	64.6
Rails Per Module:	2
Distributed Load (plf):	57.41



Rail Material Specifications

Rail Selection:

SolarMount

E (psf):	1.45E+09
I (ft^4):	0.0000222
Z (ft^3):	0.000214
Fy (psf):	2736000

Rail Bending Calculations	
Allowable Bending Moment (lb-ft):	585.5
Actual Bending Moment (lb-ft):	492.29
Actual/Allowable Moment:	84%
Allowable Deflection (in):	1.41
Actual Deflection (in):	1.31
Actual/Allowable Deflection:	93%

Project SYNERGY

Quote DRB-LA-091113-1430

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Force Analysis

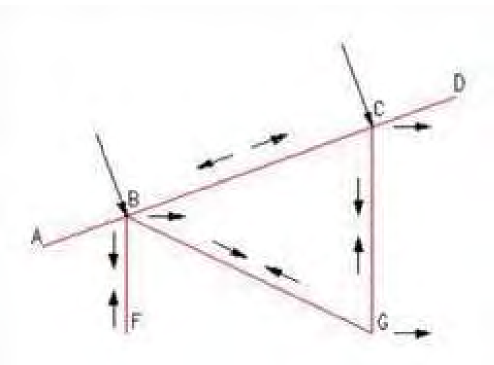
Complete

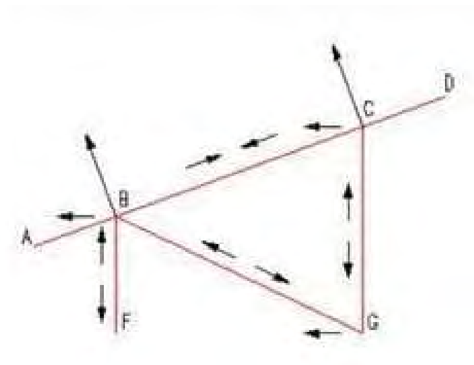
Angles

Tilt Angle (deg):	15
Cross Brace Angle (deg):	30.42
E-W Leg Spacing)	123
Rail Length:	164

Design Loads

	Downforce		Uplift	
Front Leg (psf / kip):	24.79	1.74	-8.65	-0.61
Rear Leg (psf / kip):	22.82	1.6	-14.58	-1.02





Maximum Component Forces (kips)

	Down Force	Uplift
Axial Force in Front Leg:	1.68	-0.59
Axial Force in Front Cap:	2.58	-0.75
Shear Force Front Cap:	0.9	Max Magnitude
Axail Force in Rear Leg:	1.55	-0.99
Axial Force in Rear Cap:	1.14	-0.73
Shear Force Rear Cap:	0.41	Max Magnitude
Shear Force Rear Foot:	0.9	Max Magnitude
Axial Force in N-S Brace:	0.9	-0.16
Resultant Shear N-S Brace:	0.78	Max Magnitude
Resultant Axial N-S Brace:	0.46	-0.08
Axial Force Rail:	0.41	-0.26
Resultant Shear Rail:	0.11	Max Magnitude
Resultant Axial Rail:	0.4	-0.25

Project SYNERGY | **Quote** DRB-LA-091113-1430

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Column Buckling Analysis

Complete

Front Leg Design

Pipe Selection: 3 in.Schedule 40

E (ksi):	29
Fy (ksi):	35
r (in):	1.17

Front Leg Column Calculations

Length:	56.36
Eff. Column Len. Fac:	1
Eff. Column Length:	56.36
Slenderness Ratio:	48.17
Critical Force:	18.62
Actual Force:	1.68
Ratio To Allowable:	9.02%

Rear Leg Design

Pipe Selection: 3 in.Schedule 40

E (ksi):	29
Fy (ksi):	35
r (in):	1.17

Rear Leg Column Calculations

Length:	82.09
Eff. Column Len. Fac:	1
Eff. Column Length:	82.09
Slenderness Ratio:	70.16
Critical Force:	16.3
Actual Force:	1.55
Ratio To Allowable:	9.51%

Rail Design

Rail Selection: SolarMount

E (ksi):	10.1
Fy (ksi):	19
r (in):	0.829
Rails per EW Leg:	3.82

Rail Column Calculations

Length:	99.39
Eff. Column Len. Fac:	1
Eff. Column Length:	99.39
Slenderness Ratio:	119.89
Critical Force:	2.38
Actual Force:	0.41
Ratio To Allowable:	17.23%

N-S - Cross Brace Design

Cross Brace Selection: 3" x 3" Cross Brace

E (ksi):	10.1
Fy (ksi):	19
r (in):	1.18

Cross Brace Column Calculations

Length:	111.32
Eff. Column Len. Fac:	1
Eff. Column Length:	111.32
Slenderness Ratio:	94.34
Critical Force:	7.91
Actual Force:	0.9
Ratio To Allowable:	11.38%

Project SYNERGY | **Quote** DRB-LA-091113-1430

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City, ST, Zip:	Camp Pendleton, CA 92005	**City, ST, Zip:**	Los Angeles, CA90071	Email:	andrew.agopian@aecom.com		

Seismic Design and Analysis

Complete

Seismic Analysis Inputs

ASCE7-05 Methodology

Latitude:	0	
Longitude:	0	
Site Class:	A	
Importance Factor:	0	
Roof Height:	0	
Component Height:	0	
Ss:	0	Mapped Accel. Parameter
S1:	0	Mapped Accel. Parameter
Fa:	0	Table 1613.5.3(1)
Fv:	0	Table 1613.5.3(2)

- OR - **Direct Methodology**

Seismic Zone:	IV
Cross Brace Pairs:	1

Seismic Analysis Results

Sms:	0	Eq # 16 -37
Sm1:	0	Eq # 16 - 38
Sds:	0	Eq # 16 -39
Sd1:	0	Eq # 16 -40
Ap, Rp:	1.0, 1.5	Table 13.6 - 1
Fp LRFD:	0	Eq 13.3 - 1
Fp ASD:	0.44	per 13.1.7
Fp ASD:	0.44	
Array Weight:	3603	
Total Axial Force:	1585.52	lbs

E-W - Cross Brace Design

Cross Brace Selection: 3" x 3" Cross Brace

E (ksi):	10.1
Fy (ksi):	19
r (in):	1.18
Area (sq in):	1.38

Cross Brace Column Calculations

Max CB Length:	148.1	
Eff. Column Len. Fac:	2	
Eff. Column Length:	296.20	
Slenderness Ratio:	125.51	
Critical Force:	7.91	Kip
Actual Force:	0.79	Kip
Margin Ratio:	10.0%	

Project SYNERGY | Quote DRB-LA-091113-1430

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Footing Design

Complete

Footing Design Inputs

Footing Diameter:	12	in.
Footing Depth:	36	in.
Concrete Density:	0.15	Kcf
Soil Density:	0.1	KcF

Footing Design Calculations

Max Uplift Force:	0.99	Kip
Safety Factor:	1.67	
Required Resisting Force:	1.65	Kip
Concrete Volume:	2.36	cf
Concrete Weight:	0.35	Kip
Soil Volume:	35.17	cf
Soil Weight:	1.76	Kip
Total Weight:	2.11	Kip
Margin Ratio:	78.36%	

UNIRAC FOOTINGS WILL NOT BE USED. SEE OLD CASTLE CALCULATIONS FOR BALLASTS.

Project	SYNERGY	Quote	DRB-LA-091113-1430

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Cap and Foot Design

Complete

Front Cap Design

Cap Selection: Steel - 3" Front Cap
Pipe Selection: 3 in.Schedule 40

	Axial Compression (kip)	Axial Tension (kip)	Shear (kip)
Allowable:	8	-4	4
Actual:	2.58	-0.75	0.9
Margin Ratio:	32.25%	18.75%	22.50%

Rear Cap Design

Cap Selection: Steel - 3" Front Cap

	Axial Compression (kip)	Axial Tension (kip)	Shear (kip)
Allowable:	8	-4	4
Actual:	1.55	-0.99	0.41
Margin Ratio:	19.37%	24.75%	10.25%

~~Front Foot Design~~

	Axial Compression (kip)	Axial Tension (kip)	Shear (kip)
Actual:	2.58	-0.75	0

~~Rear Foot Design~~

	Axial Compression (kip)	Axial Tension (kip)	Shear (kip)
Actual:	1.55	-0.99	0.9

NOTE: UNIRAC FOOTINGS WILL NOT BE USED. SEE OLD CASTLE CALCULATIONS FOR BALLASTS DESIGN DETAILS.

Project	**SYNERGY**	**Quote**	**DRB-LA-091113-1430**

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City, ST, Zip:	Camp Pendleton, CA 92005	**City, ST, Zip:**	Los Angeles, CA90071	Email:	andrew.agopian@aecom.com		

Design Margin Ratios

Design Specifications and Ratios

Horizontal Pipe: 3 in.Schedule 40

	Front		Rear
Pipe Moment:	57%	Pipe Moment:	53%
Pipe Deflection:	29%	Pipe Deflection:	27%

Rail Specification, Beam and Column Design Ratios

Rail Selection:	SolarMount
Rail Bending Moment:	84%
Rail Bending Deflection:	93%
Rail Buckling:	17.23%

Vertical Pipe Specifications and Column Design Ratios

Front Leg Buckling:	9.02%
Rear Leg Buckling:	9.51%
N-S Brace Buckling:	11.38%

Seismic Design Ratios

Margin Ratio: 10.0%

~~Footing Design Ratios~~

~~Margin Ratio: 78.36%~~

Connection Specifications and Design Ratios

Cap Selection: Steel - 3" Front Cap

	Front		Rear
Axial Compression:	32.25%	Axial Compression:	19.37%
Axial Tension:	18.75%	Axial Tension:	24.75%
Shear:	22.50%	Shear:	10.25%

Oldcastle® Precast	PROJECT:	Camp Pendleton	PAGE:	1/10
	PRODUCT:	Ballasted Footings	BY:	LJM
	CLIENT:	AECOM	DESIGNED:	1/22/10
	NOTES: Double Post System		CHECKED:	MH
			DATE:	5/18/10

STRUCTURAL DESIGN CALCULATIONS

5/18/2010 (PRINT DATE)

DESIGNER LARRY MILLER, MS, PE

TITLE CHIEF STRUCTURAL ENGINEER

Phone # 303-791-1100

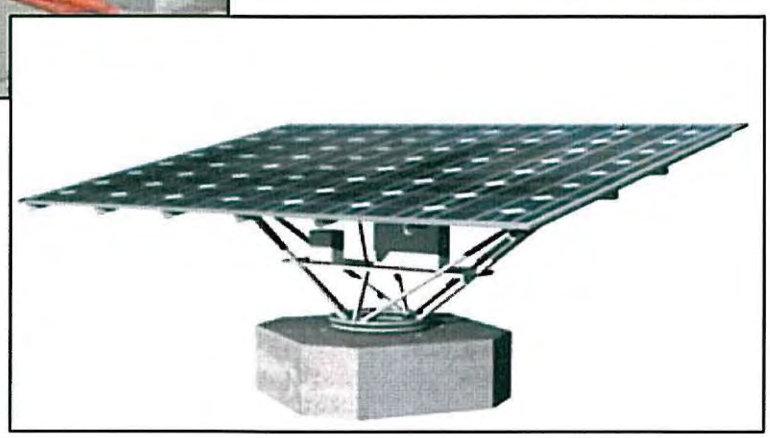
Fax Number 303-791-1101

THE FOLLOWING DESIGN CALCULATIONS WERE BASED ON THE DESIGN CRITERIA LISTED ON THE APPROPRIATE PAGES. ANY CHANGES IN THE LOADING OR THE GEOMETRY WILL AFFECT THE DESIGN, AND THE ACTING ENGINEER MUST BE NOTIFIED IMMEDIATELY PRIOR TO FABRICATION.

10 PAGES

REGISTERED PROFESSIONAL ENGINEER
MICHAEL B. HAWES
C068692
Exp. 9-30-11
CIVIL
STATE OF CALIFORNIA

5-18-10



CODE REFERENCES WERE MADE WHEN APPLICABLE/OTHERWISE BASIC ENGINEERING APPLIED

PROJECT: Camp Pendleton		PAGE:	2/10
PRODUCT: Ballasted Footings		BY:	LJM
CLIENT: AECOM		DESIGNED:	1/22/10
NOTES: Double Post System		CHECKED:	MH
		DATE:	5/18/10

Oldcastle® Precast

ALL DESIGN CRITERIA LISTED AND ASSUMPTIONS MUST BE VERIFIED BY CUSTOMER

DESIGN SPECIFICATIONS:

AMERICAN CONCRETE INSTITUTE (ACI 318-05)

ASCE/SEI 7-05 MINIMUM DESIGN LOADS FOR BUILDINGS AND OTHER STRUCTURES

Design Criteria / Assumptions:

a. *Design Wind Pressure, P per ASCE 7 - 05, Section 6.5.13.2 & Equation 6-25 for tilt angles 0 - 45 degrees*

b. *Net Pressure Coefficients, C_N per ASCE 7 - 05, figure 6-18A, for tilt angles 0 - 45 degrees*

c. Center of panel coincides with center of footings

d. ASCE Design Variables:

Design Wind Speed:	V =	85	ASCE Section 6.5.4 & Fig. 6-1A
Importance Factor:	I =	0.87	ASCE Section 6.5.5 & Table 6-1
Occupancy Category		I	ASCE Section 1.5 & Table 1-1
Surface Roughness	B, C, or D =	C	ASCE Section 6.5.6.2
Exposure Coefficient:	K_z =	0.85	ASCE Section 6.5.6 & Table 6-3
Directionality Factor:	K_d =	0.85	ASCE Section 6.5.4.4 & Table 6-4
Topographic Conditions:	K_{ZT} =	1.00	ASCE Section 6.5.7 & Fig. 6-4
Gust Effect Factor:	G =	0.85	ASCE Section 6.5.8
Velocity Pressure:	q_z =	11.63	ASCE Section 6.5.10, $= 0.00256 \times K_z \times K_{zt} \times K_d \times V^2 \times I$

e. Material Characteristics:

Concrete Density	γ_C =	150	PCF
Compressive Strength	f'c =	4000	PSI - Minimum Strength
Allowable Bearing Press:	q_A =	600	PSF
Friction Coefficient	μ =	0.49	Granular Fill Sub grade (US Dep. of the Navy)
Yield Strength	Fy =	60000	PSI

f. Design Combinations for Global Stability and Strenght Design (ASCE 2.3 & 2.4):

Overturning / Sliding	DL = 0.60	WL = 1.00	SF = 1.00
Sliding	DL = 0.60	WL = 1.00	SF = 1.00
Bearing	DL = 1.00	WL = 1.00	
Reinforcing and Shear	DL = 1.20	WL = 1.60	

g. Seismic and Snow Load Analysis available upon Request

PROJECT:	Camp Pendleton	PAGE:	3/10
PRODUCT:	Ballasted Footings	BY:	LJM
CLIENT:	AECOM	DESIGNED:	1/22/10
NOTES:	Double Post System	CHECKED:	MH
		DATE:	5/18/10

Oldcastle® Precast

GEOMETRIC INPUT VARIABLES: SOLAR PANEL PROPERTIES

				Inches	S.I.
Number of Ballasts per Array	# =	4	#		
Posts per Ballast (1 or 2)	N =	2	#		
Total Panel Width	W =	37.67	FT	452.04	11.47 m
Total Panel Length	L =	13.67	FT	164.04	4.16 m
Max Panel Rotation	θ_{max} =	15.00	DEGREES		15 Deg
Leading Edge Height, ho top of footing	ho =	4.00	FT	48.00	1.22 m
Post Spacing	S1 =	8.00	FT	96.00	2.44 m
Racking Weight	R_{DL} =	2000.00	LB		909 kg
Solar Panel Weight	P_{DL} =	2.50	PSF		12 kg / m^2
Center of Panel Offset (+ / -)		0.00	FT	0.00	0.00 m

FOUNDATION PROPERTIES

Foundation Shape		Rectangular	
Foundation Thickness	T =	1.50	FT
Total Foundation Length	L_f =	10.00	FT
Major Foundation Width	B1 =	1.50	FT
Surface Area		15.00	SQ FT
Weight		3375.00	LBS
Volume		0.83	Yd^3

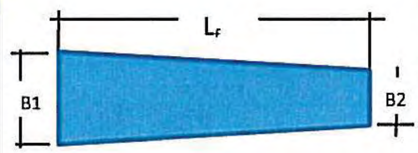
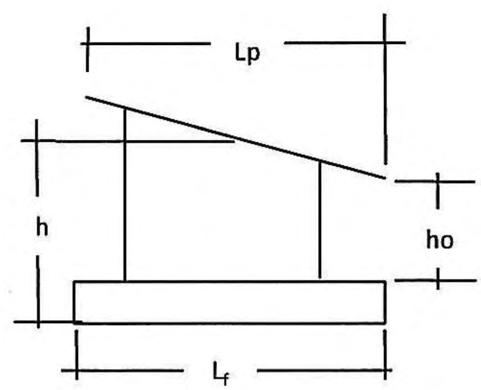


Figure 1 - Foundation Shapes

Geometrical Checks		
Lp =	13.20	FT
h =	7.27	FT
h / Lp =	0.55	
OK: 0.25 < h/Lp < 1.00 per requirements of ASCE 7 05 Figure 6-18A		

Stability Checks	
Overturning	PASS
Sliding	PASS
Bearing	PASS



Oldcastle® Precast			
PROJECT:	Camp Pendleton	PAGE:	4/10
PRODUCT:	Ballasted Footings	BY:	LJM
CLIENT:	AECOM	DESIGNED:	1/22/10
NOTES:	Double Post System	CHECKED:	MH
		DATE:	5/18/10

WIND DATA / PRESSURE & FORCE CALCULATIONS:

Pressure Coefficients, CN per ASCE 7 - 05, figure 6-18A, for tilt angles 0 - 45 degrees

Plus and Minus signs signify pressures acting towards and away from the top of the structure, respectively.

	Wind Direction y = 0		Wind Direction y = 180	
Case	C_{NW}	C_{NL}	C_{NW}	C_{NL}
A	-0.90	-1.30	1.30	1.60
B	-1.90	0.00	1.80	0.60

Resulting Pressures from Pressure Coefficients: P= qZ x G X CN per Section 6.5.13.2, MWFRs

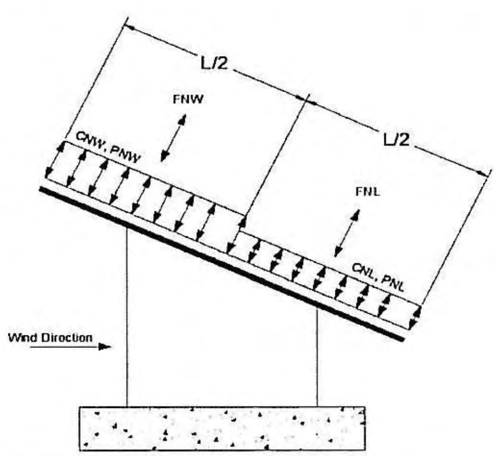
Plus and Minus signs signify pressures acting towards and away from the top of the structure, respectively.

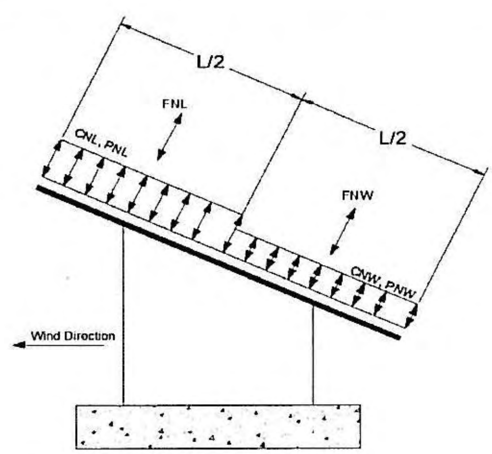
	Wind Direction y = 0		Wind Direction y = 180	
Case	P_{NW}	P_{NL}	P_{NW}	P_{NL}
A	-8.89 PSF	-12.85 PSF	12.85 PSF	15.81 PSF
B	-18.78 PSF	0.00 PSF	17.79 PSF	5.93 PSF

Resulting Normal Forces from Pressures Per Array: F= P x D x L/2

Plus and Minus signs signify forces acting towards and away from the top of the structure, respectively.

	Wind Direction y = 0		Wind Direction y = 180	
Case	F_{NW}	F_{NL}	F_{NW}	F_{NL}
A	-2289.97 LBS	-3307.74 LBS	3307.74 LBS	4071.06 LBS
B	-4834.39 LBS	0.00 LBS	4579.95 LBS	1526.65 LBS

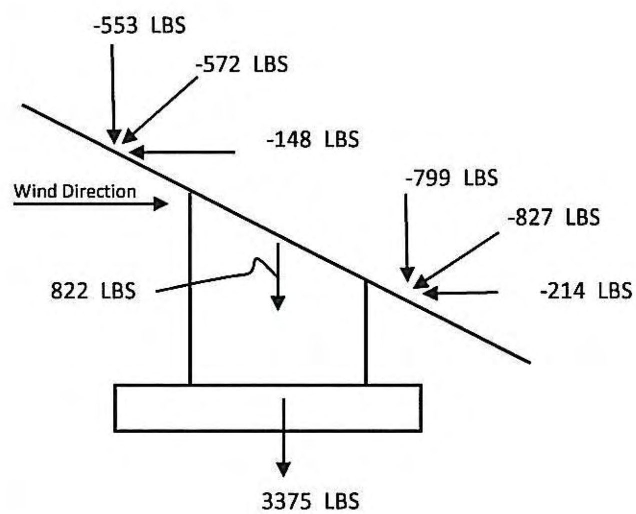




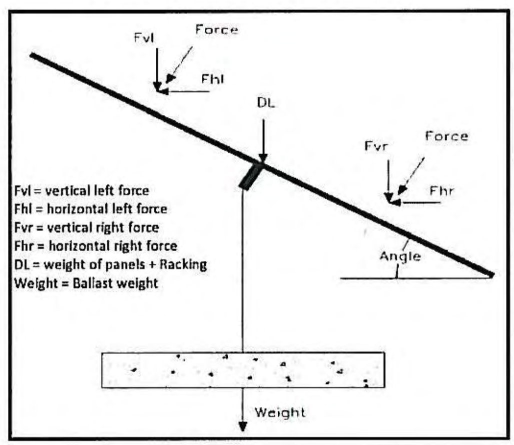
PROJECT:	Camp Pendleton	PAGE:	5/10
PRODUCT:	Ballasted Footings	BY:	LJM
CLIENT:	AECOM	DESIGNED:	1/22/10
NOTES: Double Post System		CHECKED:	MH
		DATE:	5/18/10

FORCE CALCULATIONS: UN - FACTORED FORCES PER BALLASTED FOOTING:

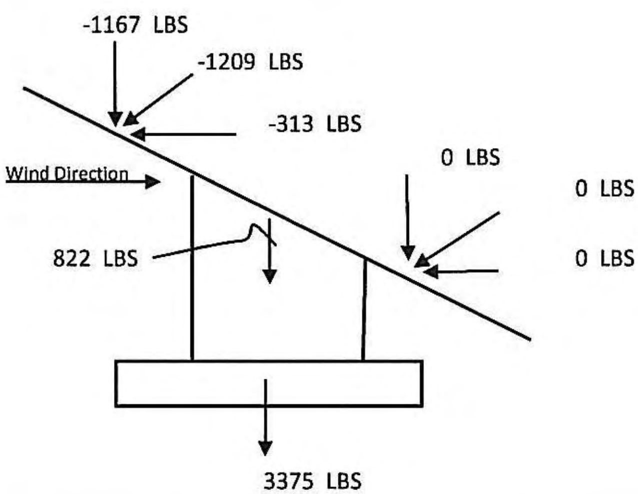
Wind Direction y = 0, Case A



Force Diagram and Sign Convention (+)



Wind Direction y = 0, Case B



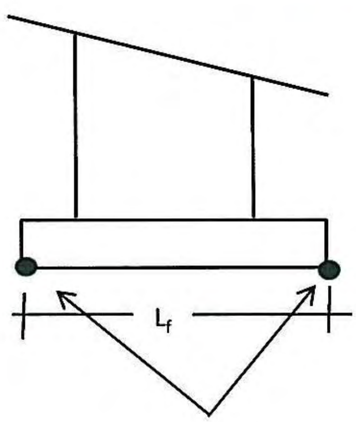
PROJECT: Camp Pendleton		PAGE:	6/10
PRODUCT: Ballasted Footings		BY:	LJM
CLIENT: AECOM		DESIGNED:	1/22/10
NOTES: Double Post System		CHECKED:	MH
		DATE:	5/18/10

STABILITY CALCULATIONS
Overturning about Foundation Length "L_f", & Sliding Resistance Calculations

Minimum Safety Factors

Overturning	1.00
Sliding	1.00

Wind Direction y = 0, Case A			Wind Direction y = 0, Case B		
Overturning			**Overturning**		
Moverturning	8522	LB- FT	Moverturning	12241	LB- FT
Mresisting	12591	LB- FT	Mresisting	12591	LB- FT
SF	1.50	OK	SF	1.00	OK
About Right Edge Controlls			**About Right Edge Controlls**		
Sliding			**Sliding**		
Normal Force	572	LBS	Normal Force	662	LBS
Sliding Force	362	LBS	Sliding Force	313	LBS
S.F.	1.60	OK	S.F.	2.10	OK



Program Checks Overturning about left and right edges

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PRODUCT:	Ballasted Footings	BY:	LJM
CLIENT:	AECOM	DESIGNED:	1/22/10
NOTES:	Double Post System	CHECKED:	MH
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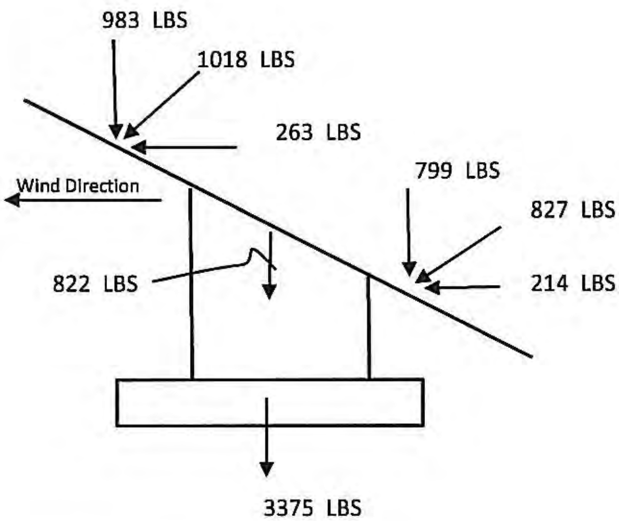
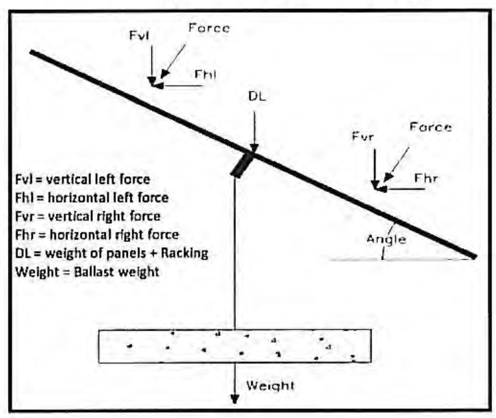
FORCE CALCULATIONS: UN - FACTORED FORCES PER BALLASTED FOOTING:

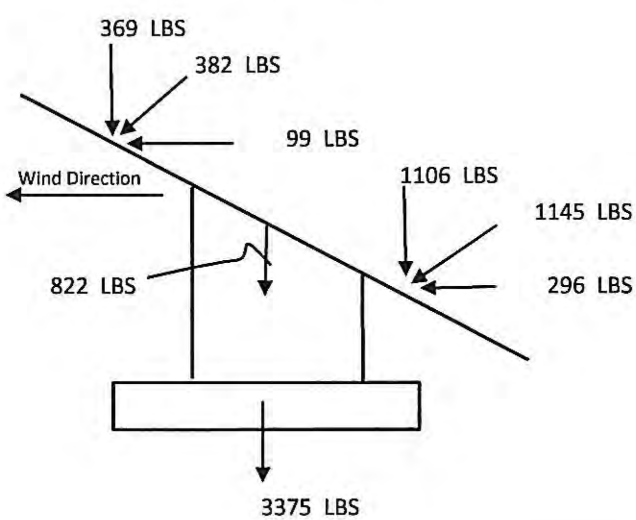
Wind Direction y = 180, Case A



Force Diagram and Sign Convention (+)



Wind Direction y = 180, Case B



PROJECT:	Camp Pendleton	PAGE:	8/10
PRODUCT:	Ballasted Footings	BY:	LJM
CLIENT:	AECOM	DESIGNED:	1/22/10
NOTES:	Double Post System	CHECKED:	MH
		DATE:	5/18/10

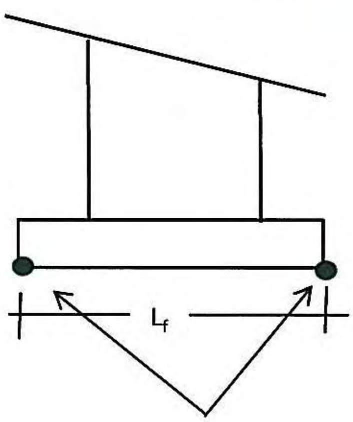
STABILITY CALCULATIONS

Overturning about Foundation Length "L_f", & Sliding Resistance Calculations

Minimum Safety Factors

Overturning	1.00
Sliding	1.00

Wind Direction y = 180, Case A			**Wind Direction y = 180, Case B**		
Overturning			**Overturning**		
Moverturning	3514.24	LB- FT	Moverturning	2697.43	LB- FT
Mresisting	20891.27	LB- FT	Mresisting	22397.59	LB- FT
SF	5.90	OK	SF	8.30	OK
About Left Edge Controlls			**About Left Edge Controlls**		
Sliding			**Sliding**		
Normal Force	2106.98	LBS	Normal Force	1956.44	LBS
Sliding Force	477.44	LBS	Sliding Force	395.13	LBS
S.F.	4.40	OK	S.F.	5.00	OK



Program Checks Overturning about left and right edges

PROJECT:	Camp Pendleton	PAGE:	9/10
PRODUCT:	Ballasted Footings	BY:	LJM
CLIENT:	AECOM	DESIGNED:	1/22/10
NOTES: Double Post System		CHECKED:	MH
		DATE:	5/18/10

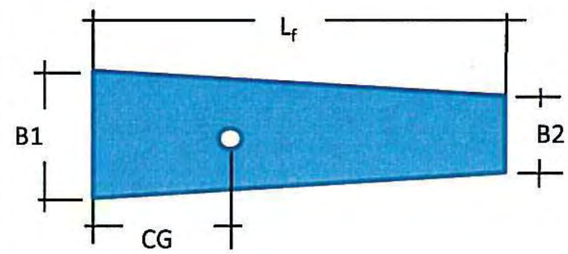
Stability Calculations: Continued

Bearing Pressure Calculations

Case	Qmax (PSF)	Qmin (PSF)	Pressure Type	Qallowable (PSF)	Contact Length (FT)	
Wind Direction y = 0, Case A	260.20	119.14	Trapezoidal	600	10.00	OK
Wind Direction y = 0, Case B	466.53	0.00	Triangular	600	8.66	OK
Wind Direction y = 180, Case A	563.49	233.67	Trapezoidal	600	10.00	OK
Wind Direction y = 180, Case B	388.64	367.56	Trapezoidal	600	10.00	OK

Section Properties <u>Utilized</u> For Bearing Contact Pressures

Foundation Thickness	1.50	FT
Total Foundation Length	10.00	FT
Major Foundation Width, B1	1.50	FT
Minor Foundation Width, B2	1.50	FT
** **Foundation Area**	15.00	SQ FT
Foundation Volume	22.50	CU FT
** **C. G.**	5.00	FT
** **I**	125.00	FT^3



**** For Trapeziums B1 = B2 is assumed to simplify calculations for determining bearing contact pressure and area**

Figure 6 - Bearing Pressure Resultants

PROJECT:	Camp Pendleton	PAGE:	10/10
PRODUCT:	Ballasted Footings	BY:	LJM
CLIENT:	AECOM	DESIGNED:	1/22/10
NOTES:	Double Post System	CHECKED:	MH
		DATE:	5/18/10

Summary - Design Assumptions and Methodology

Note: The footings may Increase / Decrease in size depending on the site survey, reviewing building authority and specifications, and if a geotechnical study is done which could alter Oldcastle's design assumptions.

Design Codes:

AMERICAN CONCRETE INSTITUTE (ACI 318-05)
ASCE/SEI 7-05 MINIMUM DESIGN LOADS FOR BUILDINGS AND OTHER STRUCTURES

Design Criteria for Calculating Wind Pressures:

Design Wind Speed:	85	MPH
Exposure Category:	C	
Occupancy Category:	I	
Importance Factor:	0.87	

Soil and Site Conditions:

Friction Coefficient:	0.49	Granular Fill Sub grade (US Dep. of the Navy)
Allowable Bearing Pressure :	600	PSF

Solar Array Parameters:

Solar Array Width:	37.67	FT
Solar Array Length:	13.67	FT
Racking Weight:	2000.00	Lbs
Panel Weight:	2.50	PSF
Leading Edge Height:	4.00	FT - Top of Footing

Solar Footing Parameters:

# Footings per Array:	4		
Footing Shape:	Rectangular		
Footing Width, B1:	*1.50*	FT	0.00 FT
Footing Thickness	1.50	FT	
Footing Length:	10.00	FT	
Footing Weight:	3375	Lbs	
Footing Volume:	0.83	YD^3	

Oldcastle Precast®

SEISMIC STABILTIY CALCULATIONS

FOR

PRECAST CONCRETE SOLAR BALLAST

REGISTERED PROFESSIONAL ENGINEER
MICHAEL B. HAWES
C068692
Exp. 9-30-11
CIVIL
STATE OF CALIFORNIA

5-18-10

CAMP PENDLETON
AECOM/SYNERGY

SPECIFICATIONS:

DESIGN/ LOADING:	ASCE 7-05
	IBC 2006

DESIGN LOADS:

SEISMIC:	1.233g 0.2 SEC. SPECTRAL RESPONSE ACCELERATION 0.710g 1 SEC. SPECTRAL RESPONSE ACCELERATION SITE LATITUDE 33.2338 SITE LONGITUDE -117.3806

CONDITIONS:

OCCUPANCY:	CATEGORY I
SEISMIC:	SEISMIC DESIGN CATEGORY D
	SITE CLASS D

General Design Parameters

Dead Loads

$H := 7.27ft$		The average height of the building.
$H_b := 1.5ft$		Height of ballast
$w_b := 1.5ft$		Width of ballast.
$L_b := 10ft$		Length of ballast
$n_b := 4$		Number of Ballast per Array
$\gamma_c := 150pcf$		Unit weight of concrete
$W_{b1} := H_b \cdot w_b \cdot L_b \cdot \gamma_c$	$W_{b1} = 3375\,lbf$	Weight of single ballast
$W_b := n_b \cdot W_{b1}$	$W_b = 13500\,lbf$	Weight of concrete ballast only (per array)
$W_c := 3600lbf$		Weight of solar Components per Unirac ULA Rack Calcs
$W := W_b + W_c$	$W = 17100\,lbf$	Effective Seismic Weight of fully equipped ballast

Seismic Loads

$\rho_{eq} := 1.0$		Redundancy Factor. Sec. 12.3.4.1, pg. 126.
$I_p := 1.0$		Importance factor. Table 11.5-1, pg. 116
$S_S := 1.233$		Maximum considered 0.2 sec. spectral response acceleration (5% of critical damping)
$S_1 := 0.710$		Maximum considered 1.0 sec. spectral response acceleration (5% of critical damping)
SiteClass := "D"		Site class. Sec. 20.1, pg. 205 (If the site class is F, a soils report will be required)
$F_a = 1.01$		Site coefficient defined in Table 11.4-2, pg. 115
$F_v = 1.5$		Site coefficient defined in Table 11.4-1, pg. 115
$S_{DS} := \frac{2}{3} \cdot S_S$	$S_{DS} = 0.822$	Design Spectral Acceleration Parameter. Eq. 11.4-3, pg. 115
$S_{D1} := \frac{2}{3} \cdot S_1$	$S_{D1} = 0.473$	Design Spectral Acceleration Parameter. Eq. 11.4-4, pg. 115

Precast Concrete Ballast - Nonbuilding Structure (ASCE 7-05, 15.4)

$R := 3.25$	Seismic Coefficients for Nonbuilding Structures Similar to Buildings. Table 15.4-1 ASCE 7-05 Assume - Ordinary steel concentrically braced frame	
$C_{s1} := \dfrac{S_{DS}}{\dfrac{R}{I_p}}$	$C_{s1} = 0.253$	Equivalent Lateral Force - Seismic Response Coefficient ASCE 7-05 (Eq. 12.8-2) pg. 129
$C_{s2} := \dfrac{0.8 \cdot S_1}{\dfrac{R}{I_p}}$	$C_{s2} = 0.175$	Nonbuilding Structures - Seismic Response Coefficient ASCE 7-05 (Eq. 15.4-2) pg. 162
$C_s := \max(C_{s1}, C_{s2})$	$C_s = 0.253$	Design Seismic Response Coefficient
$V := C_s \cdot W$	$V = 4325\,\text{lbf}$	Design Base Shear
$Q_E := V$	$Q_E = 4325\,\text{lbf}$	Effects of horizontal seismic forces Vr and Fp ASCE 7-05 Eq. 12.4-3.
$E_v := 0.2 \cdot S_{DS} \cdot W$	$E_v = 2811\,\text{lbf}$	Effect of vertical seismic forces ASCE 7-05 Eq. 12.4-2.
$E_h := \rho_{eq} \cdot Q_E$	$E_h = 4325\,\text{lbf}$	Effect of horizontal seismic forces ASCE 7-05 Eq. 12.4-1.

Sliding Check

$\mu := 0.49$		Assumed Friction Coefficient
$0.9 \cdot D + \dfrac{E_h}{1.4}$		Load Combo IBC 2006 Sect. 1605.3.2 Eq 16-21
$D := (0.9 - 0.2 \cdot S_{DS}) \cdot W$	$D = 12579\,\text{lbf}$	Effective Dead weight with Vertical Seismic and Load factors
$SR_{friction} := D \cdot \mu$	$SR_{friction} = 6164\,\text{lbf}$	Maximum allowable sliding resistance
Check that $E_h < Max_{SR}$	$SF_{sliding} := \dfrac{SR_{friction}}{\dfrac{E_h}{1.4}}$	$SF_{sliding} = 2.00$

Overturning Check

$H_{poa} := H_b + 4in$ $\quad H_{poa} = 1.83\,ft$ — Assumed height of Point of Attactment - Height that base shear acts through for overturning check

$M_{overturning} := V \cdot H_{poa}$ $\quad M_{overturning} = 7929 \cdot ft \cdot lbf$

$M_{restoring} := D \cdot \frac{L_b}{2}$ $\quad M_{restoring} = 62894 \cdot ft \cdot lbf$

$SF_{overturning} := \frac{M_{restoring}}{M_{overturning}}$ $\quad SF_{overturning} = 7.9$

Soil Bearing Check

$D_{soil} + \frac{E_h}{1.4}$ — Load Combo IBC 2006 Sect. 1605.3.2 Eq 16-20

$D_{soil} := \left(1 + 0.2 \cdot S_{DS}\right) \cdot W$ $\quad D_{soil} = 19911\,lbf$ — Effective Dead weight with Vertical Seismic and Load factors

$D_{soil} := W + E_v$ $\quad D_{soil} = 19911\,lbf$

$e := \frac{M_{overturning}}{D_{soil}}$ $\quad e = 0.4\,ft$ — Equivalent eccentricity

$\frac{L_b}{6} = 1.67\,ft$ $\quad Check := if\left(e < \frac{L_b}{6}, \text{"OK"}, \text{"Use Different Formula NG"}\right)$ — $Check = \text{"OK"}$

$q_{max} := \frac{D_{soil} \cdot \left(1 + \frac{6e}{L_b}\right)}{w_b \cdot L_b \cdot n_b}$ $\quad q_{max} = 411 \cdot psf$ — Maximum Net Bearing Pressure

$q_{min} := \frac{D_{soil} \cdot \left(1 - \frac{6e}{L_b}\right)}{w_b \cdot L_b \cdot n_b}$ $\quad q_{min} = 253 \cdot psf$ — Minimum Net Bearing Pressure

$q_{allowable} := 600psf$ — Allowable Bearing Pressure Per Customer Recommendation

$Check := if\left(q_{allowable} > q_{max}, \text{"OK"}, \text{"NG"}\right)$ — $Check = \text{"OK"}$

Basis of Design for Box Canyon PV System

Geotechnical

Prepared For:

Naval Facilities Engineering Command and

Marine Corps Base Camp Pendleton

Prepared By:

AECOM

THE ENGINEERING PARTNERS, INC.
9565 WAPLES STREET, SUITE 100
SAN DIEGO, CA 92121
(858) 824-1761

Synergy Electric
"Working Together"

AECOM

System Summary

GEOTECHNICAL SUMMARY

Site Details		
Site Location	Marine Corps Base Camp Pendleton	
Site Description	Box Canyon Landfill	
Site Latitude	33.2° N	
Item	**Value**	**Justification**
Allowable Soil Bearing Capacity	600 to 800 psf	ET cover detail, NAVFAC DM 7.2
Settlement Estimate	½ to 1 inch ET Cover, 12 to 18 inches MSW decomposition	ET cover detail, "Principles of Foundation Engineering, 4th Edition" Das, Experience with landfills
Allowable Sliding Resistance	Sliding Coefficient 0.49	Concrete to gravel interface, see attached calculation
Global Stability – Static	FS=1.38	Eid, Stark, Evans and Sherry, 2000
Global Stability – Pseudostatic	FS = 0.8	Eid, Stark, Evans and Sherry, 2000
Seismic Displacement	2" to 3"	Makdisi Seed, 1978
Peak Ground Acceleration	0.497 g	USGS Hazard Maps for MCE
Earthquake Magnitude	7.0	USGS Deaggregation

AECOM

Basis of Design

1. Ballast Design

    1.1. Designed in accordance with ACI 318-05, IBC 2006, ASCE 7-05 based on uplift forces from rack system analysis (see calculations).

    1.2. Pre-stressed steel reinforcement conforming to ASTM A-416 low relaxation grade 270, spirals to ASTM A82

    1.3. 18 to 24 inches wide by 10 foot long pre-stressed concrete

    1.4. Bearing on the surface of the ET Cover

    1.5. Ballast will bear on compacted gravel pad

    1.6. Surface of cover will be stripped of vegetation prior to placement of gravel

2. Settlement Analysis

    2.1. Settlement will only occur in cover materials, stress increase at the base of the cover is negligible

    2.2. The stress increase caused by each ballast will not overlap and the footings will act independently

    2.3. A global analysis considering a uniform load over the entire array is not required

3. Global Stability Analysis

    3.1. Properties of the ET cover based on the description provided in previous documents

    3.2. Properties for the waste based on "Municipal Solid Waste Slope Failure I: Waste and Foundation Soil Properties" Eid, Stark, Evans and Sherry, Journal of Geotechnical and Geoenvironmental Engineering, May 2000, Vol. 126, No. 5

    3.3. The critical cross section was selected for the greatest slope height along the PV array. The slope was modeled at 2.5h to 1 v and a slope height of 20 feet was selected. A uniform surcharge was applied conservatively to the edge of the slope. The geologic cross section from the 2000 USACE report which corresponds to the area of interest is attached. The groundwater table and approximate limits of the project are highlighted.

    3.4. Pseudostatic FS less than 1.5 therefore displacement analysis was required. Analysis was performed using the procedure recommended in "Simplified Procedure for Estimating Dam and Embankment Earthquake Induced Deformations", Journal of Geotechnical Engineering, July 1978, Vol. 104, No. GT7.

Calculations

See geotechnical analysis located in the “Calculations” section. Calculations reviewed by civil engineer of record.

AECOM

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847 279 2500 tel
847 279-2510 fax

March 24, 2010

Ms. Annika Moman, CEM
Project Manager
AECOM
440 Stevens Avenue, Suite 250
Solana Beach, CA 92075

Ms. Momann:

AECOM has performed the following calculations:

- Bearing Capacity Analysis dated February 9, 2010
- Settlement of Individual footings dated February 9, 2010
- Global Settlement Analysis dated March 11, 2010 and March 19, 2010
- Coefficient of Sliding Between Ballast and Gravel Subgrade dated March 11, 2010
- Static Slope Stability Analysis dated March 10, 2010
- Pseudostatic Slope Stability Analysis dated March 10, 2010
- Makdisi-Seed Slope Deformation Analysis dated March 10, 2010

AECOM has reviewed the calculations prepared by UnirRac and Old Castle for general content and use in our analysis. We find their calculations in general accordance with the design criteria for this project.

Respectfully,

3-24-10

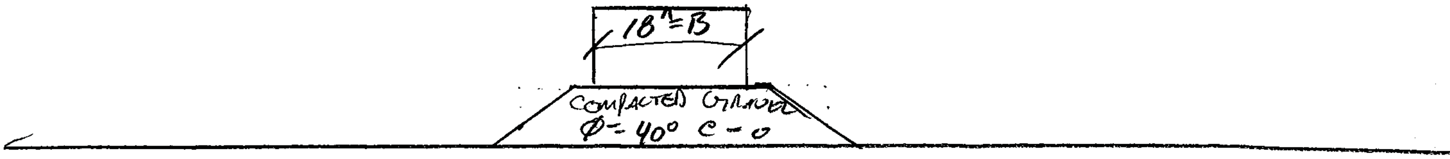
Jeremy M. Thomas, P.E.
C-73551

REGISTERED PROFESSIONAL ENGINEER
JEREMY M. THOMAS
C-73551
Exp. 12-31-10
CIVIL
STATE OF CALIFORNIA

AECOM

Calculation Sheet

Project	Subject			
Camp Pendleton	Bearing Capacity			
Originated By SMT	**Date** 5-5-10	**Checked By** [signature]	**Date** 5.5.10	**AECOM Job No.**	**Scale**	**Sheet No.** ___ Of ___



ET Cover $\gamma = 115$

$\phi = 20°$

C = 42 psf per 2000 USACE Report

FROM BOWLES USE WEIGHTED AVERAGES OF c + ϕ FOR CALCS

$$\phi_{AVE} = \tan^{-1}\left(\frac{H_1 \tan\phi_1 + H_2 \tan\phi_2}{H}\right)$$

$$C_{AV} = \frac{H_1 C_1 + H_2 C_2}{H}$$

From Bowles $H \approx B$

$$\phi = \tan^{-1}\left(\frac{6'' \cdot \tan 40 + 12'' \tan 20}{18''}\right) = 27.6° \Rightarrow \text{say } 27°$$

$$C = \frac{12 \cdot 42}{18} = 28 \text{ psf}$$

$$q_{ULT} = c N_c + \tfrac{1}{2} B \gamma N_\gamma$$

$$N_c = 29.24 \quad N_\gamma = 11.60$$

$$q = (28\text{ psf})(29.24) + (\tfrac{1}{2})(1.5)(115)(11.60) = 1819.2$$

$$q_a \text{ Dead} = \frac{1819.2}{3} = 600 \text{ psf} \qquad q_a \text{ live} = 600 \cdot 1.33 = 800 \text{ psf}$$

AECOM

Calculation Sheet

Project CAMP PENDELTON SOLAR ARRAY				Subject GEOTECHNICAL BASIS OF DESIGN		
Originated By SMT	Date 2-9-10	Checked By [illegible]	Date 3.12.10	AECOM Job No. 60145077	Scale	Sheet No. 1 Of 2

ET COVER CONSISTS OF

NOTE: BEARING PRESSURE CALCULATION HAS BEEN REVISED. SEE PREVIOUS PAGE FOR UPDATED CALCULATIONS.

48" PERMEABLE MATERIAL
COMPACTED TO 85% TO 90% MODIFIED PROCTOR
- BASED ON PERMEABILITY ASSUME SM TO SP MATERIAL
$\phi = 28°$

12" LOW PERMEABILITY COMPACTED LINER

FOR 85% TO 90% MODIFIED PROCTOR, ASSUME RELATIVE DENSITY OF 25%.

REFER TO ATTACHED SHEET 7.1-149
$\phi = 28°$
$\gamma_d = 100\ pcf$

MOISTURE CONTENT OF THIS LAYER IS LIKELY ON THE ORDER OF 15%

TOTAL UNIT WEIGHT IS $\gamma_d (1+\omega) = (100)(1.15) = 115\ pcf$

$q_{ULT} = \gamma D N_q + 0.4 \gamma B N_\gamma$

FROM 7.2-131 $N_\gamma = 13$ $N_q = 17$ $D = 1'$

$q_{ULT} = (115)(1)(17) + (0.4)(115)(1.15)(B) = 2852$

AECOM

Calculation Sheet

Project CAMP PENDELTON SOLAR ARRAY				Subject GEOTECHNICAL BOD		
Originated By SMT	Date 2-9-10	Checked By	Date 3.12.10	AECOM Job No. 60145077	Scale	Sheet No. 2 of 2

~~$q_{all} = \frac{q_{ult}}{3} = 950$ psf~~

CHECK SETTLEMENT

USE ELASTIC SETTLEMENT OF SAND

$E_s = 1{,}500$ psi

$\mu_s = 0.2$

$$S_e = \frac{B q_o}{E_s}(1-\mu_s^2)(\alpha_r)$$

$\alpha_r = 2.1$

$q_o = 700$ psf $= 4.86$ psi

$$S_e = \frac{(18'')(4.86\text{ psi})}{1{,}500\text{ psi}}(1-0.2^2)(2.1) = 0.12''$$

SOIL CONDITIONS WILL BE VARIABLE, ASSUME SETTLEMENT OF COVER WILL RANGE FROM 1/2" TO 1"

CHECK 24" WIDE FOOTING

$q_u = (115)(1)(17) + (0.4)(115)(2)(13) = 3151$

$q_a = 1{,}000$ psf

$$E_s = \frac{(24'')\left(\frac{900\text{ psf}}{144}\right)}{1{,}500\text{ psi}}(1-0.2^2)(2.1) = 0.2'' \Rightarrow \tfrac{1}{2}'' \text{ TO } 1'' \text{ OKAY}$$

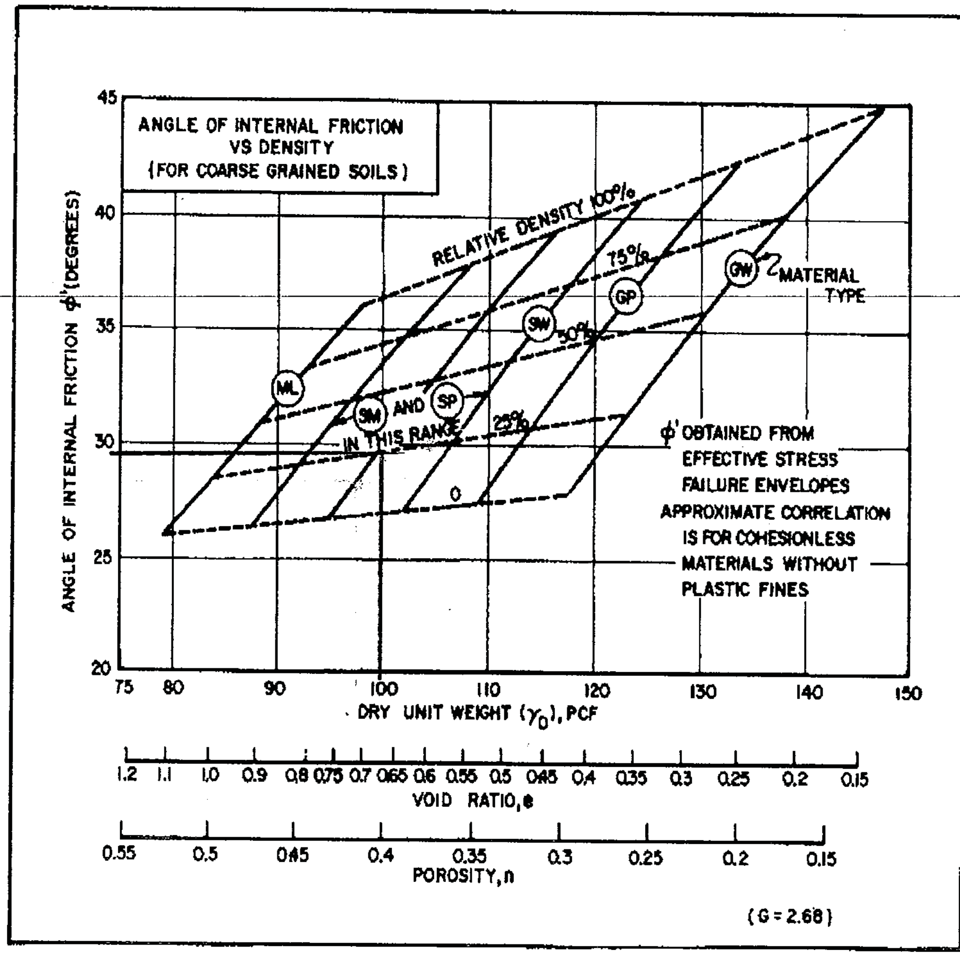
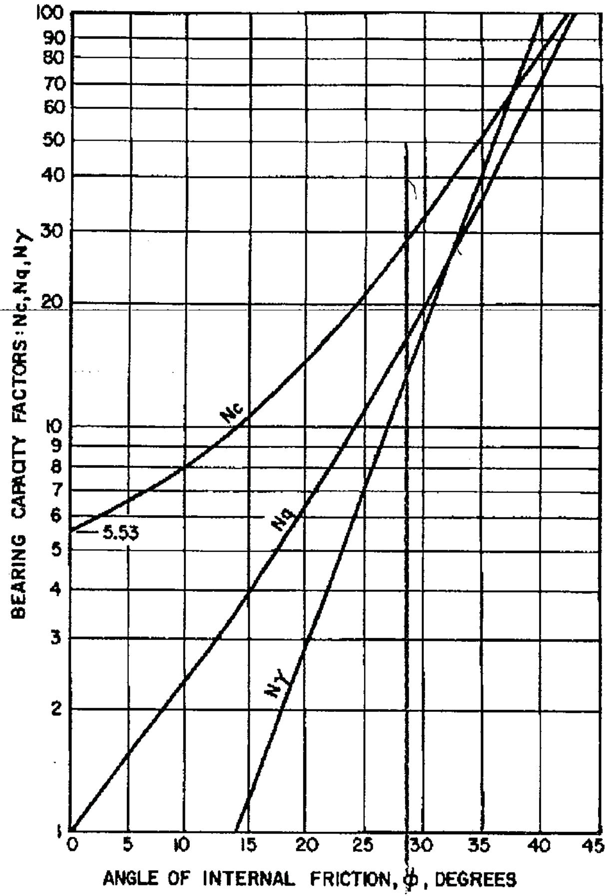


FIGURE 7
Correlations of Strength Characteristics for Granular Soils



ULTIMATE BEARING CAPACITY = q_{ult}

CONTINUOUS FOOTING; GENERAL CASE

$q_{ult} = q' + q''$

q' = PORTION OF BEARING CAPACITY ASSUMING WEIGHTLESS FOUNDATION SOIL

q'' = PORTION OF BEARING CAPACITY FROM WEIGHT OF FOUNDATION SOILS

$q' = cN_c + \gamma D N_q$

$q'' = \gamma \frac{B}{2} N_\gamma$

$q_{ult} = cN_c + \gamma D N_q + \frac{\gamma B}{2} N_\gamma$

SQUARE OR RECTANGULAR FOOTING

$q_{ult} = cN_c\,(1 + .3\frac{B}{L}) + \gamma D N_q + 0.4\gamma B N_\gamma$

CIRCULAR FOOTING: $R = B/2$

$q_{ult} = 1.3\,cN_c + \gamma D N_q + 0.6\gamma R N_\gamma$

FOR COHESIONLESS FOUNDATION SOILS ($c = 0$)

CONTINUOUS FOOTING:

$q_{ult} = \gamma D N_q + \frac{\gamma B}{2} N_\gamma$

SQUARE OR RECTANGULAR FOOTING:

$q_{ult} = \gamma D N_q + 0.4\gamma B N_\gamma$

CIRCULAR FOOTING:

$q_{ult} = \gamma D N_q + 0.6\gamma R N_\gamma$

FOR COHESIVE FOUNDATION SOILS ($\phi = 0$)

CONTINUOUS FOOTING:

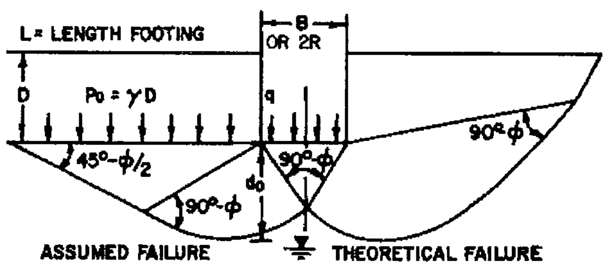
$q_{ult} = cN_c + \gamma D$

SQUARE OR RECTANGULAR FOOTING:

$q_{ult} = cN_c(1 + .3\frac{B}{L}) + \gamma D$

CIRCULAR FOOTING:

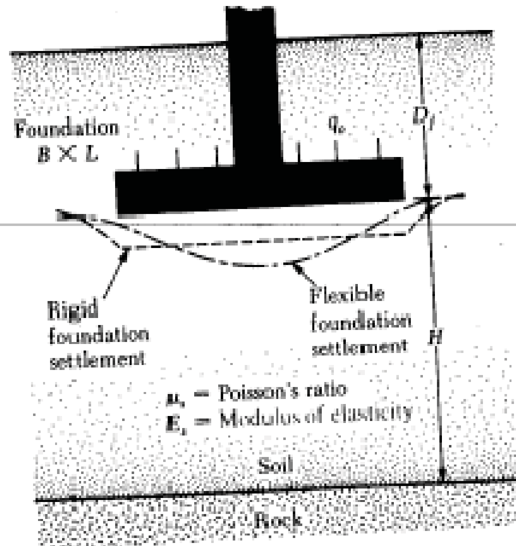
$q_{ult} = 1.3\,cN_c + \gamma D$



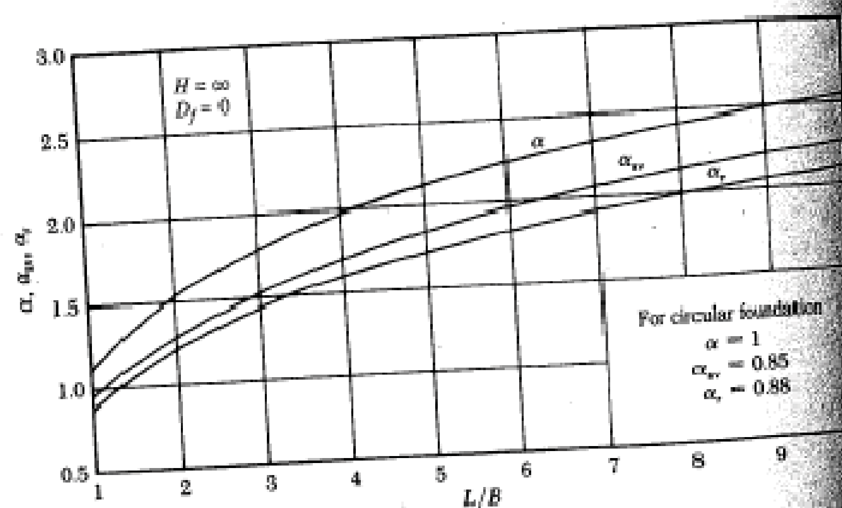
ASSUMED CONDITIONS:

1. $D \leq B$
2. SOIL IS UNIFORM TO DEPTH $d_o > B$.
3. WATER LEVEL LOWER THAN d_o BELOW BASE OF FOOTING.
4. VERTICAL LOAD CONCENTRIC.
5. FRACTION AND ADHESION ON VERTICAL SIDES OF FOOTING ARE NEGLECTED.
6. FOUNDATION SOIL WITH PROPERTIES c, ϕ, γ

FIGURE 1
Ultimate Bearing Capacity of Shallow Footings With Concentric Loads



▼ **FIGURE 4.17** Elastic settlement of flexible and rigid foundations



▼ **FIGURE 4.18** Values of α, α_{av}, and α_r — Eqs. (4.28), (4.29), (4.32), and (4.32a)

$$\boxed{S_e = \frac{Bq_o}{E_s}(1-\mu_s^2)\alpha_{av} \qquad \text{(average for flexible foundation)}} \tag{4.32}$$

Figure 4.18 also shows the values of α_{av} for various L/B ratios of foundation.

However, if the foundation shown in Figure 4.17 is rigid, the immediate settlement will be different and may be expressed as

$$\boxed{S_e = \frac{Bq_o}{E_s}(1-\mu_s^2)\alpha_r \qquad \text{(rigid foundation)}} \tag{4.32a}$$

The values of α_r for various L/B ratios of foundation are shown in Figure 4.18.

If $D_f = 0$ and $H < \infty$ due to the presence of a rigid (incompressible) layer as shown in Figure 4.17,

$$S_e = \frac{Bq_o}{E_s}(1-\mu_s^2)\,\frac{[(1-\mu_s^2)F_1 + (1-\mu_s-2\mu_s^2)F_2]}{2} \tag{4.33a}$$

(corner of flexible foundation)

and

$$S_e = \frac{Bq_o}{E_s}(1-\mu_s^2)\,[(1-\mu_s^2)F_1 + (1-\mu_s-2\mu_s^2)F_2] \tag{4.33b}$$

(corner of flexible foundation)

The variations of F_1 and F_2 with H/B are given in Figures 4.19 and 4.20, respectively (Steinbrenner, 1934).

It is also important to realize that the preceding relationships for S_e assume that the depth of the foundation is equal to zero. For $D_f > 0$, the magnitude of S_e will decrease.

Hence the immediate settlement is calculated as

$$
\begin{aligned}
S_e &= C_1 C_2 (\bar{q} - q) \sum \frac{I_z}{E_s} \Delta z \\
&= (0.893)(1.34)(178.54 - 31.39)(18.95 \times 10^{-5}) \\
&= 0.03336 \approx 33 \text{ mm}
\end{aligned}
$$

After five years, the actual *maximum* settlement observed for the foundation was about 39 mm.

4.11 RANGE OF MATERIAL PARAMETERS FOR COMPUTING ELASTIC SETTLEMENT

Sections 4.8–4.10 presented the equations for calculating immediate settlement of foundations. These equations contain the elastic parameters, such as E_s and μ_s. If the laboratory test results for these parameters are not available, certain realistic assumptions have to be made. Table 4.5 shows the approximate range of the elastic parameters for various soils.

Several investigators have correlated the values of the modulus of elasticity, E_s, with the field standard penetration number, N_F and the cone penetration resistance q_c. Mitchell and Gardner (1975) compiled a list of these correlations. Schmertmann (1970) indicated that the modulus of elasticity of sand may be given by

$$E_s(\text{kN/m}^2) = 766N_F \tag{4.36}$$

where N_F = field standard penetration number

In English units

$$E\ (\text{U.S. ton/ft}^2) = 8N_F \tag{4.37}$$

▼ **TABLE 4.5** Elastic Parameters of Various Soils

Type of soil	Modulus of elasticity, E_s		Poisson's ratio, μ
	lb/in²	MN/m²	
Loose sand	1,500–3,500	10.35–24.15	0.20–0.40
Medium dense sand	2,500–4,000	17.25–27.60	0.25–0.40
Dense sand	5,000–8,000	34.50–55.20	0.30–0.45
Silty sand	1,500–2,500	10.35–17.25	0.20–0.40
Sand and gravel	10,000–25,000	69.00–172.50	0.15–0.35
Soft clay	600–3,000	4.1–20.7	
Medium clay	3,000–6,000	20.7–41.4	0.20–0.50
Stiff clay	6,000–14,000	41.4–96.6	

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Calculation Sheet

Project CAMP PENDLETON				Subject GLOBAL SETTLEMENT		
Originated By SMT	Date 3-11-10	Checked By [illegible]	Date 3.12.10	AECOM Job No. 60145077	Scale	Sheet No. 1 Of 1

- FOR GLOBAL SETTLEMENT ONLY CONSIDER DEAD LOAD
- PER OLDCASTLE, WEIGHT OF RACK AND PANELS = 3,600 #

$$\frac{3{,}600\#}{4 \text{ FRAMES}} = 900\# / \text{FRAME}$$

- WEIGHT OF SINGLE BALLAST = 3,375 #

- TOTAL LOAD / BALLAST = 4,275#
- CONTACT PRESSURE = $\frac{4{,}275\#}{15ft^2}$ (BALLAST IS 1.5' X 10') = 285psf

- USING BOUSSINESQ STRESS DISTRIBUTION INCREASE IN PRESSURE AT BASE OF COVER (6') WILL BE 37psf

- FOOTINGS WILL NOT IMPACT THE WASTE

- BASED ON BOUSSINESQ CHARTS STRESS OVERLAP BETWEEN FOOTINGS AT BASE OF COVER WILL ALSO BE INSIGNIFICANT

- CONCLUSION

  THE FOUNDATIONS FOR THE RACKS WILL ACT INDEPENDENTLY OF EACH OTHER AND WILL CAUSE AN INSIGNIFICANT INCREASE IN STRESS IN THE WASTE. A GLOBAL STABILITY ANALYSIS CONSISTING OF APPLYING A UNIFORM LOAD OVER THE ENTIRE ARRAY FOOTPRINT IS NOT NECESSARY AND WOULD NOT ACCURATELY MODEL THE IMPACT OF THE RACKS ON THE LANDFILL.

AECOM

Calculation Sheet

Project	BOX CANYON			Subject	GLOBAL SETTLEMENT	
Originated By: SMT	Date: 3-19-10	Checked By: SAE	Date: 3.19.10	AECOM Job No.: 60145077	Scale	Sheet No. ____ Of ____

- MODEL THE ARRAY AS A UNIFORM SURCHARGE
- WEIGHT OF RACK, PANELS + BALLAST = 17,100 # FROM OLD CASTLE
- PROJECTED DIMENSIONS OF A SINGLE RACK = 164" X 452" FROM UNIRAC

$$\text{PROJECTED AREA} = \frac{(164)(452)}{144} \approx 515 ft^2$$

- EFFECTIVE SURCHARGE $= \frac{17{,}100\#}{515 ft^2} = \underline{\underline{33 psf}}$

- BECAUSE OF LARGE AREA OF LOAD THERE WILL EFFECTIVELY BE NO STRESS REDUCTION BELOW THE CENTER OF THE ARRAY
- ASSUME ALL MATERIALS ARE NORMALLY CONSOLIDATED
- ASSUME WORST CASE WASTE EXTENDS TO TOP OF ROCK

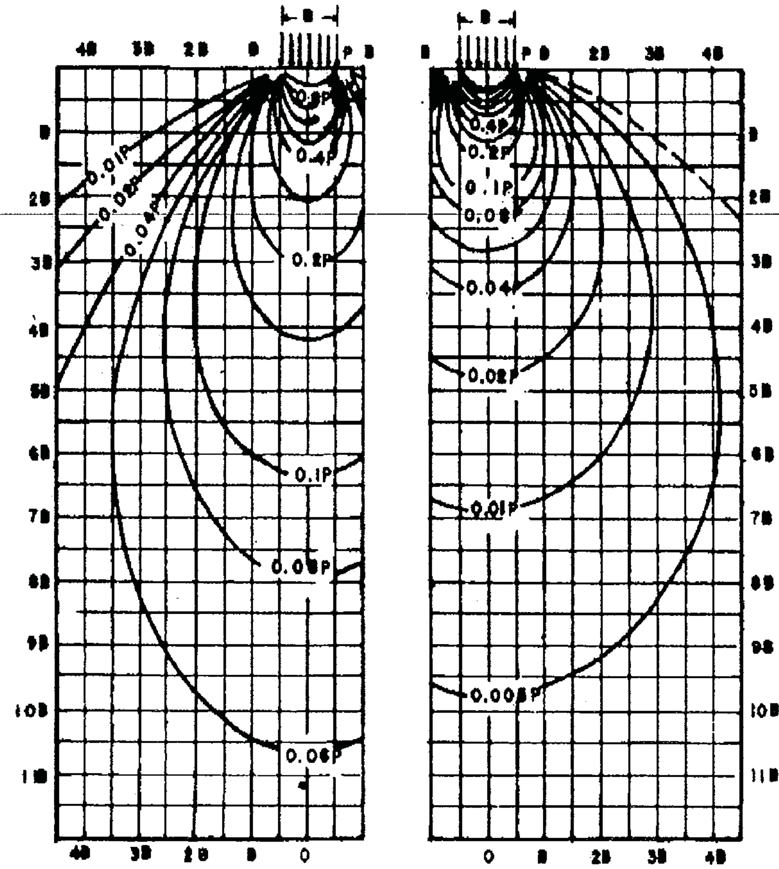
- ANALYSIS PREDICTS 0.7" OF SETTLEMENT
- ADD 0.3" FOR ELASTIC COMPRESSION

- GLOBAL SETTLEMENT WILL B ~1"

Consolidation Settlement

Layer	Top	Bottom	γt (pcf)	γ'	Cc	Ccr	Pc	e_o	σ' mid l	$\Delta\sigma_{z\ (psf)}$	$\sigma'+\Delta\sigma$	S	
Topsoil and ET Layer	0	5	120	120									
Clay Cap	5	6	120	120									
MSW	6	8	100	100	0.6	0.06	0	2	820	33	853	0.007	ft
MSW	8	10	100	100	0.6	0.06	0	2	1020	33	1053	0.006	ft
MSW	10	12	100	100	0.6	0.06	0	2	1220	33	1253	0.005	ft
MSW	12	14	100	100	0.6	0.06	0	2	1420	33	1453	0.004	ft
MSW	14	16	100	100	0.6	0.06	0	2	1620	33	1653	0.004	ft
MSW	16	18	100	100	0.6	0.06	0	2	1820	33	1853	0.003	ft
MSW	18	20	100	100	0.6	0.06	0	2	2020	33	2053	0.003	ft
MSW	20	22	100	100	0.6	0.06	0	2	2220	33	2253	0.003	ft
MSW	22	24	100	100	0.6	0.06	0	2	2420	33	2453	0.002	ft
MSW	24	26	100	100	0.6	0.06	0	2	2620	33	2653	0.002	ft
MSW	26	28	100	100	0.6	0.06	0	2	2820	33	2853	0.002	ft
MSW	28	30	100	100	0.6	0.06	0	2	3020	33	3053	0.002	ft
MSW	30	32	120	120	0.6	0.06	0	2	3240	33	3273	0.002	ft
MSW	32	34	120	120	0.6	0.06	0	2	3480	33	3513	0.002	ft
MSW	34	36	120	120	0.6	0.06	0	2	3720	33	3753	0.002	ft
MSW	36	38	120	120	0.6	0.06	0	2	3960	33	3993	0.001	ft
MSW	38	40	120	120	0.6	0.06	0	2	4200	33	4233	0.001	ft
MSW	40	42	120	120	0.6	0.06	0	2	4440	33	4473	0.001	ft
MSW	42	44	120	120	0.6	0.06	0	2	4680	33	4713	0.001	ft
MSW	44	46	120	120	0.6	0.06	0	2	4920	33	4953	0.001	ft
MSW	46	48	120	120	0.6	0.06	0	2	5160	33	5193	0.001	ft
MSW	48	50	120	120	0.6	0.06	0	2	5400	33	5433	0.001	ft

Total Settlement 0.055 ft
0.66 inches



a. INFINITELY LONG FOOTING

b. SQUARE FOOTING

SQUARE FOOTING

GIVEN

FOOTING SIZE = 20'X 20'

UNIT PRESSURE P = 2 TSF

FIND

PROFILE OF STRESS INCREASE BENEATH CENTER OF FOOTING DUE TO APPLIED LOAD

B = 20' P = 2 TSF

z (FT)	z/B	σ_z TSF
10	0.5	0.70 X 2 = 1.4
20	1	0.38 X 2 = 0.76
30	1.5	0.19 X 2 = 0.38
40	2.0	0.12 X 2 = 0.24
50	2.5	0.07 X 2 = 0.14
60	3.0	0.05 X 2 = 0.10

FIGURE 3
Stress Contours and Their Application

Boussinesq Stress Distribution
Stress Change Below Center of Footing
Camp Pendelton Solar Array

B	1.5	ft	Ballast Width
L	10	ft	Ballast Length
z	varies	ft	Depth Below Ballast

z	m1	n1	I4	Stress increase
0.1	6.666667	0.133333	0.999	284.72
0.2	6.666667	0.266667	0.993	282.89
0.3	6.666667	0.4	0.977	278.52
0.4	6.666667	0.533333	0.952	271.43
0.5	6.666667	0.666667	0.919	262.03
0.6	6.666667	0.8	0.881	251.05
0.7	6.666667	0.933333	0.839	239.20
0.8	6.666667	1.066667	0.797	227.10
0.9	6.666667	1.2	0.755	215.17
1	6.666667	1.333333	0.715	203.69
1.1	6.666667	1.466667	0.677	192.83
1.2	6.666667	1.6	0.641	182.64
1.3	6.666667	1.733333	0.608	173.16
1.4	6.666667	1.866667	0.577	164.37
1.5	6.666667	2	0.548	156.23
1.6	6.666667	2.133333	0.522	148.70
1.7	6.666667	2.266667	0.497	141.73
1.8	6.666667	2.4	0.475	135.28
1.9	6.666667	2.533333	0.454	129.29
2	6.666667	2.666667	0.434	123.74
2.1	6.666667	2.8	0.416	118.57
2.2	6.666667	2.933333	0.399	113.75
2.3	6.666667	3.066667	0.383	109.24
2.4	6.666667	3.2	0.369	105.03
2.5	6.666667	3.333333	0.355	101.08
2.6	6.666667	3.466667	0.342	97.37
2.7	6.666667	3.6	0.329	93.88
2.8	6.666667	3.733333	0.318	90.58
2.9	6.666667	3.866667	0.307	87.47
3	6.666667	4	0.297	84.53
3.1	6.666667	4.133333	0.287	81.74
3.2	6.666667	4.266667	0.278	79.10
3.3	6.666667	4.4	0.269	76.59
3.4	6.666667	4.533333	0.260	74.20
3.5	6.666667	4.666667	0.252	71.92
3.6	6.666667	4.8	0.245	69.75
3.7	6.666667	4.933333	0.237	67.68
3.8	6.666667	5.066667	0.231	65.70
3.9	6.666667	5.2	0.224	63.80
4	6.666667	5.333333	0.217	61.99

4.1	6.666667	5.466667	0.211	60.25
4.2	6.666667	5.6	0.206	58.58
4.3	6.666667	5.733333	0.200	56.98
4.4	6.666667	5.866667	0.195	55.44
4.5	6.666667	6	0.189	53.96
4.6	6.666667	6.133333	0.184	52.54
4.7	6.666667	6.266667	0.180	51.17
4.8	6.666667	6.4	0.175	49.85
4.9	6.666667	6.533333	0.170	48.58
5	6.666667	6.666667	0.166	47.35
5.1	6.666667	6.8	0.162	46.17
5.2	6.666667	6.933333	0.158	45.03
5.3	6.666667	7.066667	0.154	43.93
5.4	6.666667	7.2	0.150	42.86
5.5	6.666667	7.333333	0.147	41.84
5.6	6.666667	7.466667	0.143	40.84
5.7	6.666667	7.6	0.140	39.88
5.8	6.666667	7.733333	0.137	38.95
5.9	6.666667	7.866667	0.134	38.05
6	6.666667	8	0.130	37.18

Calculation Sheet

Project CAMP PENDLETON				Subject SLIDING COEFFICIENT		
Originated By SMT	Date 3-11-10	Checked By [illegible]	Date 3.12.10	AECOM Job No. 60145077	Scale	Sheet No. 1 Of 1

- BALLAST WILL BE PLACED ON A COMPACTED GRAVEL PAD

- PRIOR TO PLACEMENT OF GRAVEL VEGETATION WILL BE STRIPED

- FOR COMPACTED GRAVEL A FRICTION ANGLE OF $\phi = 40^0$ CAN BE EXPECTED

- ULTIMATE FRICTION $= \tan(\phi)$

$\tan(40) = 0.83$

ALLOWABLE FRICTION BASED OF FS=1.5 IS 0.55

ASSUMED VALUE OF 0.49 O.K

Calculation Sheet

Project				Subject		
BOX CANYON				MAKDISI - SEED ANALYSIS		
Originated By: SMT	Date: 3-10-10	Checked By: DSO	Date: 3.12.10	AECOM Job No.: 60145077	Scale	Sheet No. 1 of 2

REV 1 DSO 5.17.10

USING USGS MAPS AND ASSUMING SITE CLASS D

$PGA = 0.497g$

FROM STABILITY ANALYSIS USING 80% OF PEAK STRENGTHS

$K_y = 0.13 g$ ⚠

ASSUME FAILED MASS WILL ACT AS RIGID BLOCK

$K_{max} = PGA$

$$\frac{K_y}{K_{max}} = \frac{0.13}{0.497} = 0.265$$ ⚠

✓

FROM FIG 11 OF MAKDISI SEED

$$u = (0.11)(k_{max})(g)(T_0)$$ ⚠

USING DAKOULAS + GAZETAS FORMULATION & ASSUMING CONSTANT STIFFNESS W/DEPTH

$$T_1 = \frac{(16)(\pi)}{(4)(2)(\beta_1)}\left(\frac{H}{V_s}\right)$$

$\beta_1 = 2.404$

$V_s = 800 \frac{ft}{s}$

$H = 20'$

$$T_1 = \frac{2\pi}{2.404}\left(\frac{20}{800}\right) = 0.065s$$

$$u = (0.11)(0.497)(32.2\tfrac{ft}{s^2})(0.065s) = 0.11'ft = 1.4''$$ ⚠

✓

AECOM

Calculation Sheet

Project Box Canyon				Subject Makdisi - Seed		
Originated By SMT	Date 3-10-10	Checked By [signature]	Date 3.12.10	AECOM Job No. 60145077	Scale	Sheet No. 2 of 2

Rev 1 [initials] 5.17.10

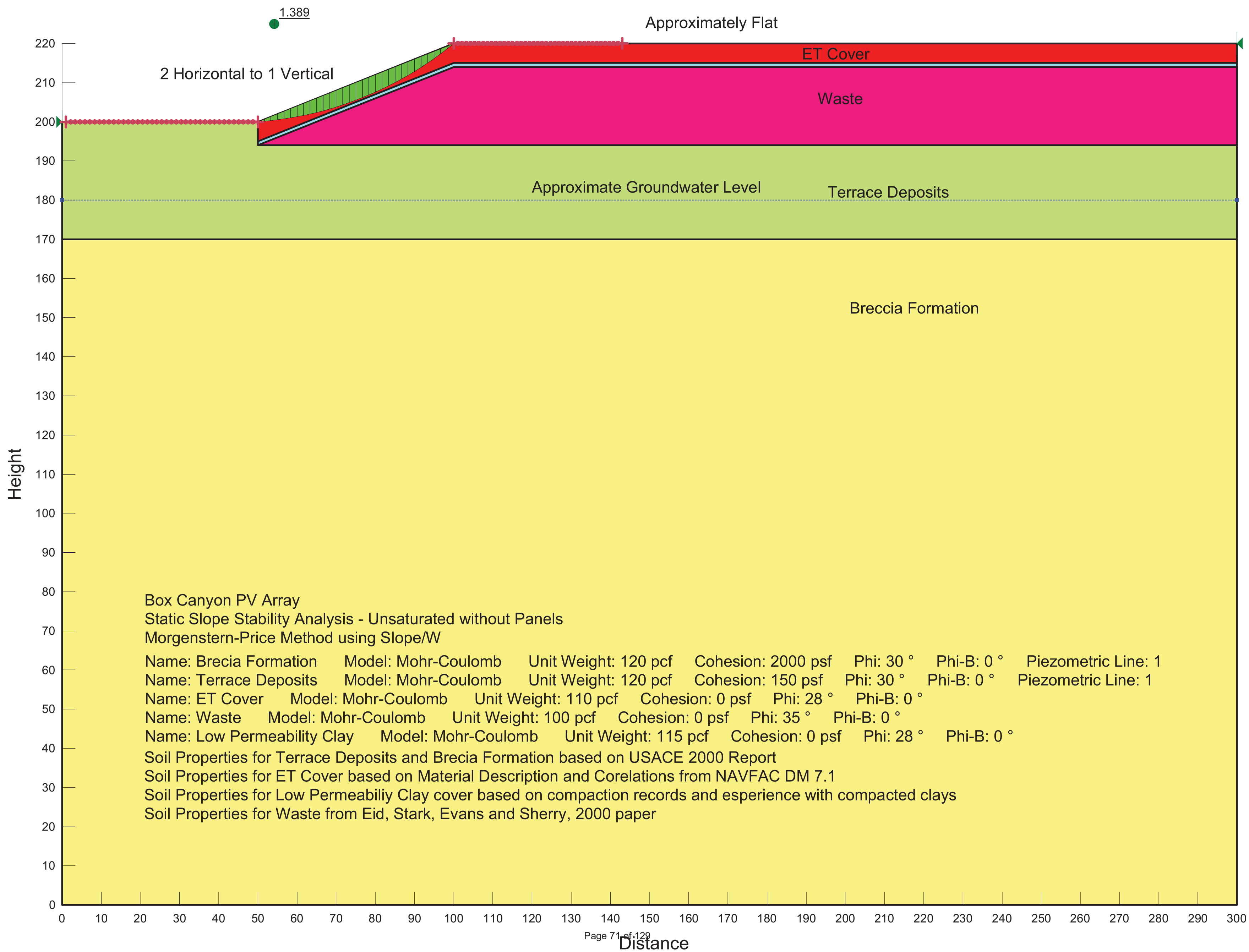
Check Lower Bound V_s of 500 ft/s

$$T_1 = \frac{2\pi}{2.404}\left(\frac{20}{500}\right) = 0.105\,s$$

$$U = (0.11)(0.497)(32.2)(0.105) = 0.185 = 2.2''$$ ⚠1 ✓

1" to 3" of Displacement can be expected

⚠1 - Revised 5-13-10 by SMT
- Modified soil strengths
- Modified yield accelerations


1.389
Approximately Flat
2 Horizontal to 1 Vertical
ET Cover
Waste
Approximate Groundwater Level
Terrace Deposits
Breccia Formation
Box Canyon PV Array
Static Slope Stability Analysis - Unsaturated without Panels
Morgenstern-Price Method using Slope/W
Name: Brecia Formation Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion: 2000 psf Phi: 30 ° Phi-B: 0 ° Piezometric Line: 1
Name: Terrace Deposits Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion: 150 psf Phi: 30 ° Phi-B: 0 ° Piezometric Line: 1
Name: ET Cover Model: Mohr-Coulomb Unit Weight: 110 pcf Cohesion: 0 psf Phi: 28 ° Phi-B: 0 °
Name: Waste Model: Mohr-Coulomb Unit Weight: 100 pcf Cohesion: 0 psf Phi: 35 ° Phi-B: 0 °
Name: Low Permeability Clay Model: Mohr-Coulomb Unit Weight: 115 pcf Cohesion: 0 psf Phi: 28 ° Phi-B: 0 °
Soil Properties for Terrace Deposits and Brecia Formation based on USACE 2000 Report
Soil Properties for ET Cover based on Material Description and Corelations from NAVFAC DM 7.1
Soil Properties for Low Permeabiliy Clay cover based on compaction records and esperience with compacted clays
Soil Properties for Waste from Eid, Stark, Evans and Sherry, 2000 paper
Height
Distance
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
220
230
240
250
260
270
280
290
300

SLOPE/W Analysis

File Information

Created By: Thomas, Jeremy
Revision Number: 31
Last Edited By: Thomas, Jeremy
Date: 6/2/2010
Time: 1:16:10 PM
File Name: Static_no panels.gsz
Directory: K:\PROJECTS\Camp Pendelton Solar Array\In_Progress\
Last Solved Date: 6/2/2010
Last Solved Time: 1:16:36 PM

Project Settings

Length(L) Units: feet
Time(t) Units: Seconds
Force(F) Units: lbf
Pressure(p) Units: psf
Strength Units: psf
Unit Weight of Water: 62.4 pcf
View: 2D

Analysis Settings

SLOPE/W Analysis

Kind: SLOPE/W
Method: Morgenstern-Price
Settings
    Apply Phreatic Correction: No
    Side Function
        Interslice force function option: Half-Sine
    PWP Conditions Source: Piezometric Line
    Use Staged Rapid Drawdown: No
SlipSurface
    Direction of movement: Right to Left
    Use Passive Mode: No
    Slip Surface Option: Entry and Exit
    Critical slip surfaces saved: 1
    Optimize Critical Slip Surface Location: No
    Tension Crack
        Tension Crack Option: (none)

FOS Distribution

FOS Calculation Option: Constant

Advanced

Number of Slices: 30

Optimization Tolerance: 0.01

Minimum Slip Surface Depth: 4 ft

Optimization Maximum Iterations: 2000

Optimization Convergence Tolerance: 1e-007

Starting Optimization Points: 8

Ending Optimization Points: 16

Complete Passes per Insertion: 1

Driving Side Maximum Convex Angle: 5 °

Resisting Side Maximum Convex Angle: 1 °

Materials

Brecia Formation

Model: Mohr-Coulomb

Unit Weight: 120 pcf

Cohesion: 2000 psf

Phi: 30 °

Phi-B: 0 °

Pore Water Pressure

Piezometric Line: 1

Terrace Deposits

Model: Mohr-Coulomb

Unit Weight: 120 pcf

Cohesion: 150 psf

Phi: 30 °

Phi-B: 0 °

Pore Water Pressure

Piezometric Line: 1

ET Cover

Model: Mohr-Coulomb

Unit Weight: 110 pcf

Cohesion: 0 psf

Phi: 28 °

Phi-B: 0 °

Waste

Model: Mohr-Coulomb

Unit Weight: 100 pcf

Cohesion: 0 psf

Phi: 35 °

Phi-B: 0 °

Low Permeability Clay

Model: Mohr-Coulomb
Unit Weight: 115 pcf
Cohesion: 0 psf
Phi: 28 °
Phi-B: 0 °

Slip Surface Entry and Exit

Left Projection: Range
Left-Zone Left Coordinate: (0.96082, 200) ft
Left-Zone Right Coordinate: (50, 200) ft
Left-Zone Increment: 40
Right Projection: Range
Right-Zone Left Coordinate: (100, 220) ft
Right-Zone Right Coordinate: (143, 220) ft
Right-Zone Increment: 40
Radius Increments: 10

Slip Surface Limits

Left Coordinate: (0, 200) ft
Right Coordinate: (300, 220) ft

Piezometric Lines

Piezometric Line 1

Coordinates

	X (ft)	Y (ft)
	0	180
	300	180

Regions

	Material	Points	Area (ft^2)
Region 1	Brecia Formation	1,2,11,10	51000
Region 2	Terrace Deposits	2,3,4,15,7,12,11	7500
Region 3	Waste	7,8,9,12	4500
Region 4	Low Permeability Clay	7,8,9,13,14,15	250

Region 5	ET Cover	15,4,5,6,13,14	1250

Points

	X (ft)	Y (ft)
Point 1	0	0
Point 2	0	170
Point 3	0	200
Point 4	50	200
Point 5	100	220
Point 6	300	220
Point 7	50	194
Point 8	100	214
Point 9	300	214
Point 10	300	0
Point 11	300	170
Point 12	300	194
Point 13	300	215
Point 14	100	215
Point 15	50	195

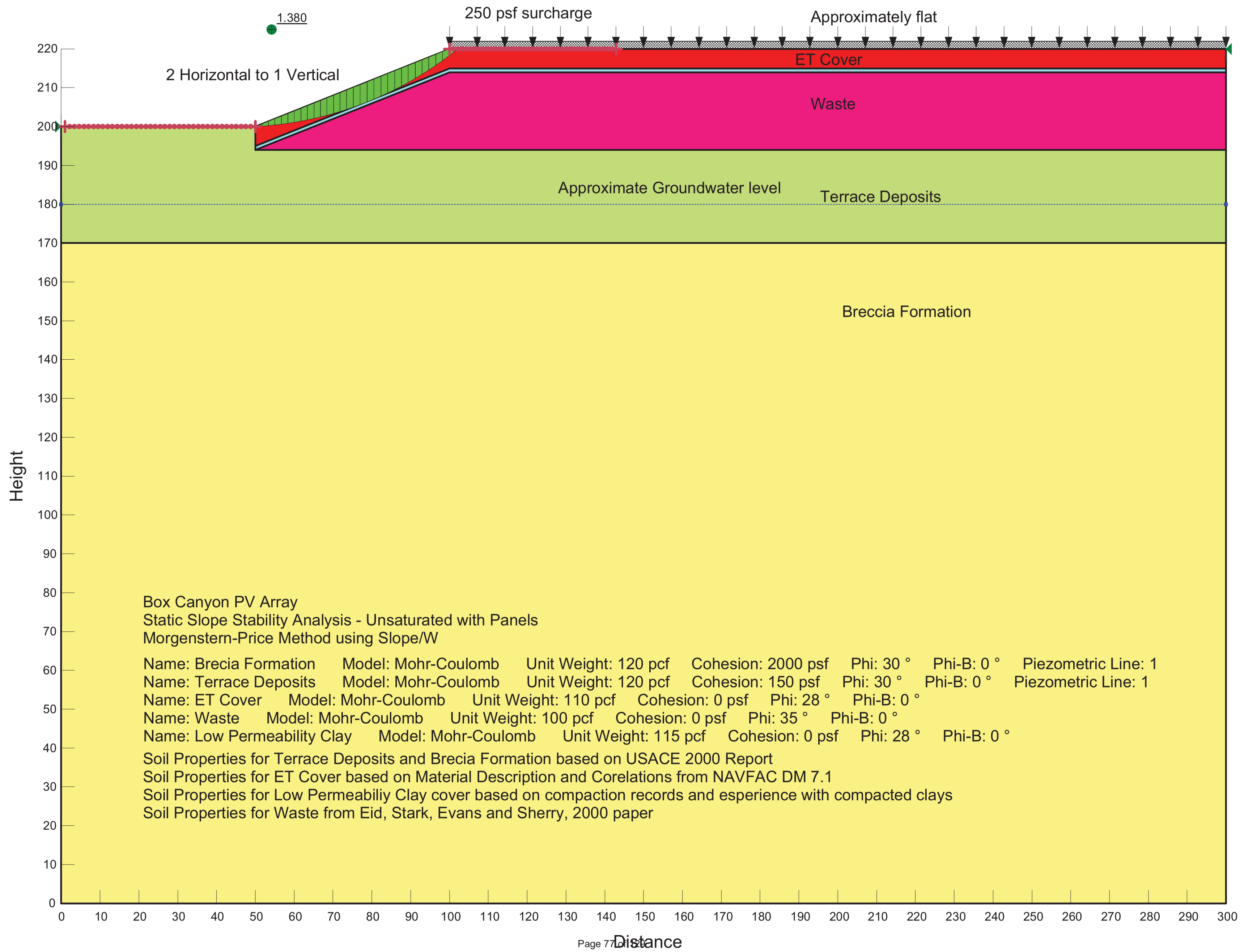
Critical Slip Surfaces

	Slip Surface	FOS	Center (ft)	Radius (ft)	Entry (ft)	Exit (ft)
1	18043	1.389	(43.669, 288.327)	88.554	(100, 220)	(50, 200)

Slices of Slip Surface: 18043

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
1	18043	50.833335	200.06765	0	28.758818	15.291335	0
2	18043	52.5	200.2188	0	85.431969	45.424984	0
3	18043	54.166665	200.4018	0	139.64825	74.25229	0
4	18043	55.833335	200.6169	0	190.77414	101.43641	0
5	18043	57.5	200.86425	0	238.1744	126.63957	0
6	18043	59.166665	201.14415	0	281.26281	149.55009	0

7	18043	60.833335	201.45695	0	319.53254	169.89847	0
8	18043	62.5	201.80295	0	352.59817	187.47977	0
9	18043	64.166665	202.1826	0	380.21875	202.16589	0
10	18043	65.833335	202.59635	0	402.30269	213.90813	0
11	18043	67.5	203.04465	0	418.91046	222.73864	0
12	18043	69.166665	203.52805	0	430.20539	228.74426	0
13	18043	70.833335	204.0472	0	436.48067	232.08089	0
14	18043	72.5	204.60275	0	438.08532	232.9341	0
15	18043	74.166665	205.19545	0	435.42403	231.51906	0
16	18043	75.833335	205.82605	0	428.89007	228.04489	0
17	18043	77.5	206.49545	0	418.88991	222.72772	0
18	18043	79.166665	207.20465	0	405.767	215.75014	0
19	18043	80.833335	207.9546	0	389.82257	207.27234	0
20	18043	82.5	208.74655	0	371.28247	197.41439	0
21	18043	84.166665	209.58175	0	350.2853	186.25	0
22	18043	85.833335	210.46155	0	326.89787	173.81468	0
23	18043	87.5	211.38755	0	301.08334	160.08885	0
24	18043	89.166665	212.3614	0	272.71459	145.00492	0
25	18043	90.833335	213.38495	0	241.55303	128.43603	0
26	18043	92.5	214.4603	0	207.26545	110.205	0
27	18043	94.166665	215.5897	0	169.39387	90.068319	0
28	18043	95.833335	216.77575	0	127.3655	67.721436	0
29	18043	97.5	218.02135	0	80.48192	42.792996	0
30	18043	99.166665	219.3297	0	27.898881	14.834098	0


1.380
250 psf surcharge
Approximately flat
2 Horizontal to 1 Vertical
ET Cover
Waste
Approximate Groundwater level
Terrace Deposits
Breccia Formation
Box Canyon PV Array
Static Slope Stability Analysis - Unsaturated with Panels
Morgenstern-Price Method using Slope/W
Name: Brecia Formation Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion: 2000 psf Phi: 30 ° Phi-B: 0 ° Piezometric Line: 1
Name: Terrace Deposits Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion: 150 psf Phi: 30 ° Phi-B: 0 ° Piezometric Line: 1
Name: ET Cover Model: Mohr-Coulomb Unit Weight: 110 pcf Cohesion: 0 psf Phi: 28 ° Phi-B: 0 °
Name: Waste Model: Mohr-Coulomb Unit Weight: 100 pcf Cohesion: 0 psf Phi: 35 ° Phi-B: 0 °
Name: Low Permeability Clay Model: Mohr-Coulomb Unit Weight: 115 pcf Cohesion: 0 psf Phi: 28 ° Phi-B: 0 °
Soil Properties for Terrace Deposits and Brecia Formation based on USACE 2000 Report
Soil Properties for ET Cover based on Material Description and Corelations from NAVFAC DM 7.1
Soil Properties for Low Permeabiliy Clay cover based on compaction records and esperience with compacted clays
Soil Properties for Waste from Eid, Stark, Evans and Sherry, 2000 paper
Height
Distance

SLOPE/W Analysis

File Information

Created By: Thomas, Jeremy
Revision Number: 34
Last Edited By: Thomas, Jeremy
Date: 6/2/2010
Time: 2:06:24 PM
File Name: Static_panels_unsat.gsz
Directory: K:\PROJECTS\Camp Pendelton Solar Array\In_Progress\Revised Slpoe Stability\6-2-10 Revision\
Last Solved Date: 6/2/2010
Last Solved Time: 4:39:10 PM

Project Settings

Length(L) Units: feet
Time(t) Units: Seconds
Force(F) Units: lbf
Pressure(p) Units: psf
Strength Units: psf
Unit Weight of Water: 62.4 pcf
View: 2D

Analysis Settings

SLOPE/W Analysis

- Kind: SLOPE/W
- Method: Morgenstern-Price
- Settings
  - Apply Phreatic Correction: No
  - Side Function
    - Interslice force function option: Half-Sine
  - PWP Conditions Source: Piezometric Line
  - Use Staged Rapid Drawdown: No
- SlipSurface
  - Direction of movement: Right to Left
  - Use Passive Mode: No
  - Slip Surface Option: Entry and Exit
  - Critical slip surfaces saved: 1
  - Optimize Critical Slip Surface Location: No
  - Tension Crack

Tension Crack Option: (none)

FOS Distribution

FOS Calculation Option: Constant

Advanced

Number of Slices: 30

Optimization Tolerance: 0.01

Minimum Slip Surface Depth: 4 ft

Optimization Maximum Iterations: 2000

Optimization Convergence Tolerance: 1e-007

Starting Optimization Points: 8

Ending Optimization Points: 16

Complete Passes per Insertion: 1

Driving Side Maximum Convex Angle: 5 °

Resisting Side Maximum Convex Angle: 1 °

Materials

Brecia Formation

Model: Mohr-Coulomb

Unit Weight: 120 pcf

Cohesion: 2000 psf

Phi: 30 °

Phi-B: 0 °

Pore Water Pressure

Piezometric Line: 1

Terrace Deposits

Model: Mohr-Coulomb

Unit Weight: 120 pcf

Cohesion: 150 psf

Phi: 30 °

Phi-B: 0 °

Pore Water Pressure

Piezometric Line: 1

ET Cover

Model: Mohr-Coulomb

Unit Weight: 110 pcf

Cohesion: 0 psf

Phi: 28 °

Phi-B: 0 °

Waste

Model: Mohr-Coulomb

Unit Weight: 100 pcf

Cohesion: 0 psf

Phi: 35 °
Phi-B: 0 °

Low Permeability Clay

Model: Mohr-Coulomb
Unit Weight: 115 pcf
Cohesion: 0 psf
Phi: 28 °
Phi-B: 0 °

Slip Surface Entry and Exit

Left Projection: Range
Left-Zone Left Coordinate: (0.96082, 200) ft
Left-Zone Right Coordinate: (50, 200) ft
Left-Zone Increment: 40
Right Projection: Range
Right-Zone Left Coordinate: (100, 220) ft
Right-Zone Right Coordinate: (143, 220) ft
Right-Zone Increment: 40
Radius Increments: 10

Slip Surface Limits

Left Coordinate: (0, 200) ft
Right Coordinate: (300, 220) ft

Piezometric Lines

Piezometric Line 1

Coordinates

	X (ft)	Y (ft)
	0	180
	300	180

Surcharge Loads

Surcharge Load 1

Surcharge (Unit Weight): 125 pcf
Direction: Vertical

Coordinates

	X (ft)	Y (ft)
	100	222
	300	222

Regions

	Material	Points	Area (ft^2)
Region 1	Brecia Formation	1,2,11,10	51000
Region 2	Terrace Deposits	2,3,4,15,7,12,11	7500
Region 3	Waste	7,8,9,12	4500
Region 4	Low Permeability Clay	7,8,9,13,14,15	250
Region 5	ET Cover	15,4,5,6,13,14	1250

Points

	X (ft)	Y (ft)
Point 1	0	0
Point 2	0	170
Point 3	0	200
Point 4	50	200
Point 5	100	220
Point 6	300	220
Point 7	50	194
Point 8	100	214
Point 9	300	214
Point 10	300	0
Point 11	300	170
Point 12	300	194
Point 13	300	215
Point 14	100	215
Point 15	50	195

Critical Slip Surfaces

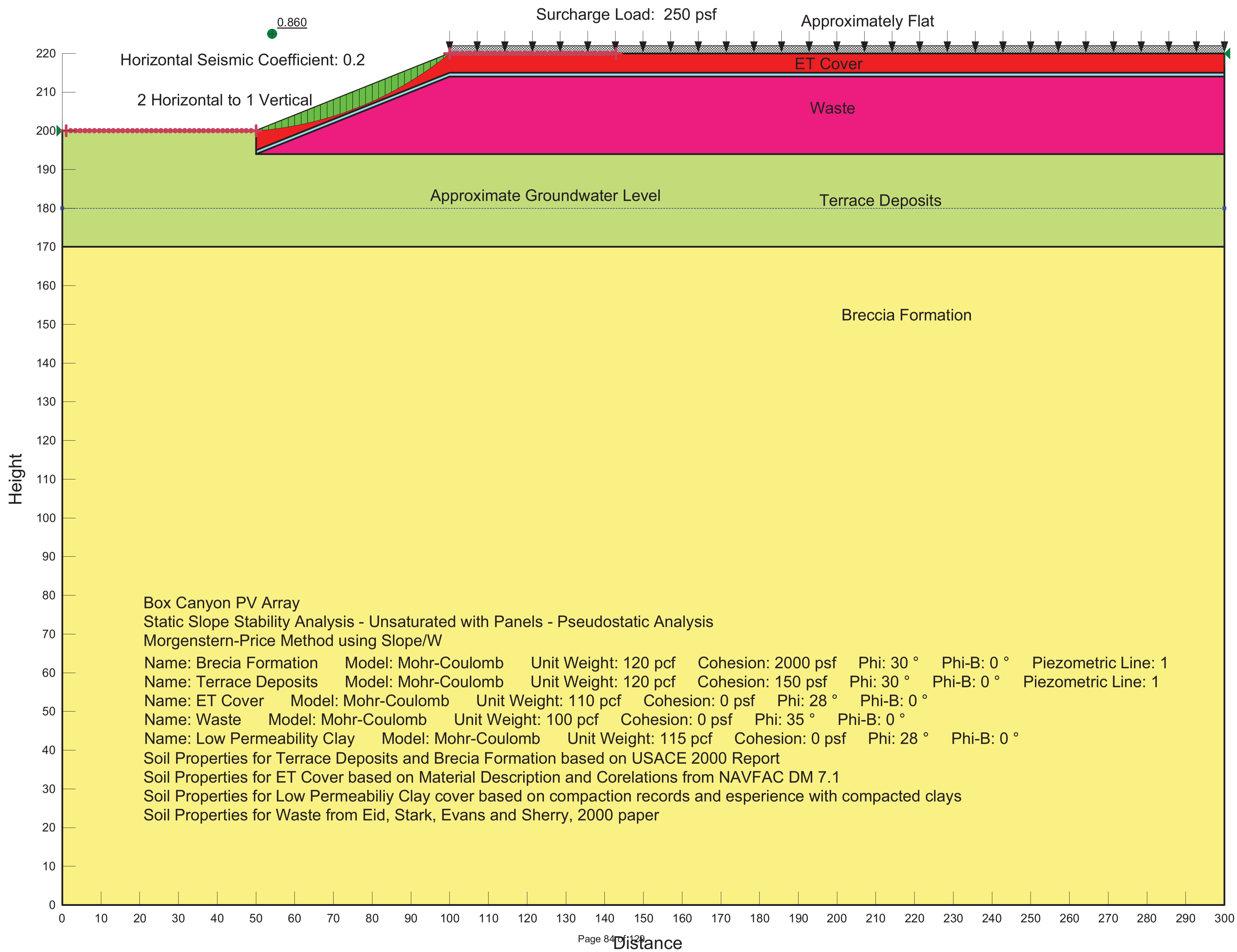
	Slip Surface	FOS	Center (ft)	Radius (ft)	Entry (ft)	Exit (ft)

1	18065	1.380	(45.245, 290.388)	90.513	(102.15, 220)	(50, 200)

Slices of Slip Surface: 18065

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
1	18065	50.838295	200.0519	0	30.935844	16.44888	0
2	18065	52.514885	200.17135	0	92.216337	49.032296	0
3	18065	54.191475	200.32215	0	151.40319	80.502504	0
4	18065	55.86806	200.5045	0	207.80616	110.4925	0
5	18065	57.544645	200.71855	0	260.71243	138.62326	0
6	18065	59.221235	200.96455	0	309.44505	164.53485	0
7	18065	60.897825	201.24275	0	353.38813	187.8998	0
8	18065	62.574415	201.55345	0	392.05826	208.46107	0
9	18065	64.251005	201.89705	0	425.10559	226.03265	0
10	18065	65.927595	202.27385	0	452.34631	240.5168	0
11	18065	67.60418	202.6843	0	473.73936	251.89169	0
12	18065	69.280765	203.1289	0	489.41708	260.22768	0
13	18065	70.957355	203.6082	0	499.63057	265.65829	0
14	18065	72.633945	204.12275	0	504.72383	268.36642	0
15	18065	74.359145	204.6902	0	505.24213	268.64201	0
16	18065	76.13296	205.3135	0	501.29219	266.54179	0
17	18065	77.906775	205.9787	0	492.93549	262.09845	0
18	18065	79.680585	206.68675	0	480.67814	255.5811	0
19	18065	81.4544	207.43875	0	464.97762	247.23298	0
20	18065	83.228215	208.23595	0	446.20177	237.24969	0
21	18065	84.997615	209.07745	0	425.00201	225.97758	0
22	18065	86.7626	209.9645	0	401.64286	213.5573	0
23	18065	88.527585	210.9006	0	375.90543	199.87246	0
24	18065	90.292575	211.88755	0	347.73421	184.89356	0
25	18065	92.05756	212.9273	0	316.95871	168.52994	0
26	18065	93.822545	214.02195	0	283.27088	150.6178	0
27	18065	95.587535	215.174	0	246.25574	130.9365	0
28	18065	97.35252	216.3861	0	205.33857	109.18046	0
29	18065	99.117505	217.6612	0	159.81545	84.975382	0

30	18065	101.075	219.15745	0	258.16496	137.26874	0



0.860
Surcharge Load: 250 psf
Approximately Flat
Horizontal Seismic Coefficient: 0.2
2 Horizontal to 1 Vertical
ET Cover
Waste
Approximate Groundwater Level
Terrace Deposits
Breccia Formation
Box Canyon PV Array
Static Slope Stability Analysis - Unsaturated with Panels - Pseudostatic Analysis
Morgenstern-Price Method using Slope/W
Name: Brecia Formation Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion: 2000 psf Phi: 30 ° Phi-B: 0 ° Piezometric Line: 1
Name: Terrace Deposits Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion: 150 psf Phi: 30 ° Phi-B: 0 ° Piezometric Line: 1
Name: ET Cover Model: Mohr-Coulomb Unit Weight: 110 pcf Cohesion: 0 psf Phi: 28 ° Phi-B: 0 °
Name: Waste Model: Mohr-Coulomb Unit Weight: 100 pcf Cohesion: 0 psf Phi: 35 ° Phi-B: 0 °
Name: Low Permeability Clay Model: Mohr-Coulomb Unit Weight: 115 pcf Cohesion: 0 psf Phi: 28 ° Phi-B: 0 °
Soil Properties for Terrace Deposits and Brecia Formation based on USACE 2000 Report
Soil Properties for ET Cover based on Material Description and Corelations from NAVFAC DM 7.1
Soil Properties for Low Permeabiliy Clay cover based on compaction records and esperience with compacted clays
Soil Properties for Waste from Eid, Stark, Evans and Sherry, 2000 paper
Height
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
220
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
220
230
240
250
260
270
280
290
300
Distance

SLOPE/W Analysis

File Information

Created By: Thomas, Jeremy
Revision Number: 40
Last Edited By: Thomas, Jeremy
Date: 6/2/2010
Time: 4:32:51 PM
File Name: Pseudostatic_panels_unsat.gsz
Directory: K:\PROJECTS\Camp Pendelton Solar Array\In_Progress\Revised Slpoe Stability\6-2-10 Revision\
Last Solved Date: 6/2/2010
Last Solved Time: 4:33:25 PM

Project Settings

Length(L) Units: feet
Time(t) Units: Seconds
Force(F) Units: lbf
Pressure(p) Units: psf
Strength Units: psf
Unit Weight of Water: 62.4 pcf
View: 2D

Analysis Settings

SLOPE/W Analysis

- Kind: SLOPE/W
- Method: Morgenstern-Price
- Settings
  - Apply Phreatic Correction: No
  - Side Function
    - Interslice force function option: Half-Sine
  - PWP Conditions Source: Piezometric Line
  - Use Staged Rapid Drawdown: No
- SlipSurface
  - Direction of movement: Right to Left
  - Use Passive Mode: No
  - Slip Surface Option: Entry and Exit
  - Critical slip surfaces saved: 1
  - Optimize Critical Slip Surface Location: No
  - Tension Crack

Tension Crack Option: (none)

FOS Distribution

FOS Calculation Option: Constant

Advanced

Number of Slices: 30

Optimization Tolerance: 0.01

Minimum Slip Surface Depth: 4 ft

Optimization Maximum Iterations: 2000

Optimization Convergence Tolerance: 1e-007

Starting Optimization Points: 8

Ending Optimization Points: 16

Complete Passes per Insertion: 1

Driving Side Maximum Convex Angle: 5 °

Resisting Side Maximum Convex Angle: 1 °

Materials

Brecia Formation

Model: Mohr-Coulomb

Unit Weight: 120 pcf

Cohesion: 2000 psf

Phi: 30 °

Phi-B: 0 °

Pore Water Pressure

Piezometric Line: 1

Terrace Deposits

Model: Mohr-Coulomb

Unit Weight: 120 pcf

Cohesion: 150 psf

Phi: 30 °

Phi-B: 0 °

Pore Water Pressure

Piezometric Line: 1

ET Cover

Model: Mohr-Coulomb

Unit Weight: 110 pcf

Cohesion: 0 psf

Phi: 28 °

Phi-B: 0 °

Waste

Model: Mohr-Coulomb

Unit Weight: 100 pcf

Cohesion: 0 psf

Phi: 35 °
Phi-B: 0 °

Low Permeability Clay

Model: Mohr-Coulomb
Unit Weight: 115 pcf
Cohesion: 0 psf
Phi: 28 °
Phi-B: 0 °

Slip Surface Entry and Exit

Left Projection: Range
Left-Zone Left Coordinate: (0.96082, 200) ft
Left-Zone Right Coordinate: (50, 200) ft
Left-Zone Increment: 40
Right Projection: Range
Right-Zone Left Coordinate: (100, 220) ft
Right-Zone Right Coordinate: (143, 220) ft
Right-Zone Increment: 40
Radius Increments: 10

Slip Surface Limits

Left Coordinate: (0, 200) ft
Right Coordinate: (300, 220) ft

Piezometric Lines

Piezometric Line 1

Coordinates

	X (ft)	Y (ft)
	0	180
	300	180

Surcharge Loads

Surcharge Load 1

Surcharge (Unit Weight): 125 pcf
Direction: Vertical

Coordinates

	X (ft)	Y (ft)
	100	222
	300	222

Seismic Loads

Horz Seismic Load: 0.2
Ignore seismic load in strength: No

Regions

	Material	Points	Area (ft^2)
Region 1	Brecia Formation	1,2,11,10	51000
Region 2	Terrace Deposits	2,3,4,15,7,12,11	7500
Region 3	Waste	7,8,9,12	4500
Region 4	Low Permeability Clay	7,8,9,13,14,15	250
Region 5	ET Cover	15,4,5,6,13,14	1250

Points

	X (ft)	Y (ft)
Point 1	0	0
Point 2	0	170
Point 3	0	200
Point 4	50	200
Point 5	100	220
Point 6	300	220
Point 7	50	194
Point 8	100	214
Point 9	300	214
Point 10	300	0
Point 11	300	170
Point 12	300	194
Point 13	300	215
Point 14	100	215
Point 15	50	195

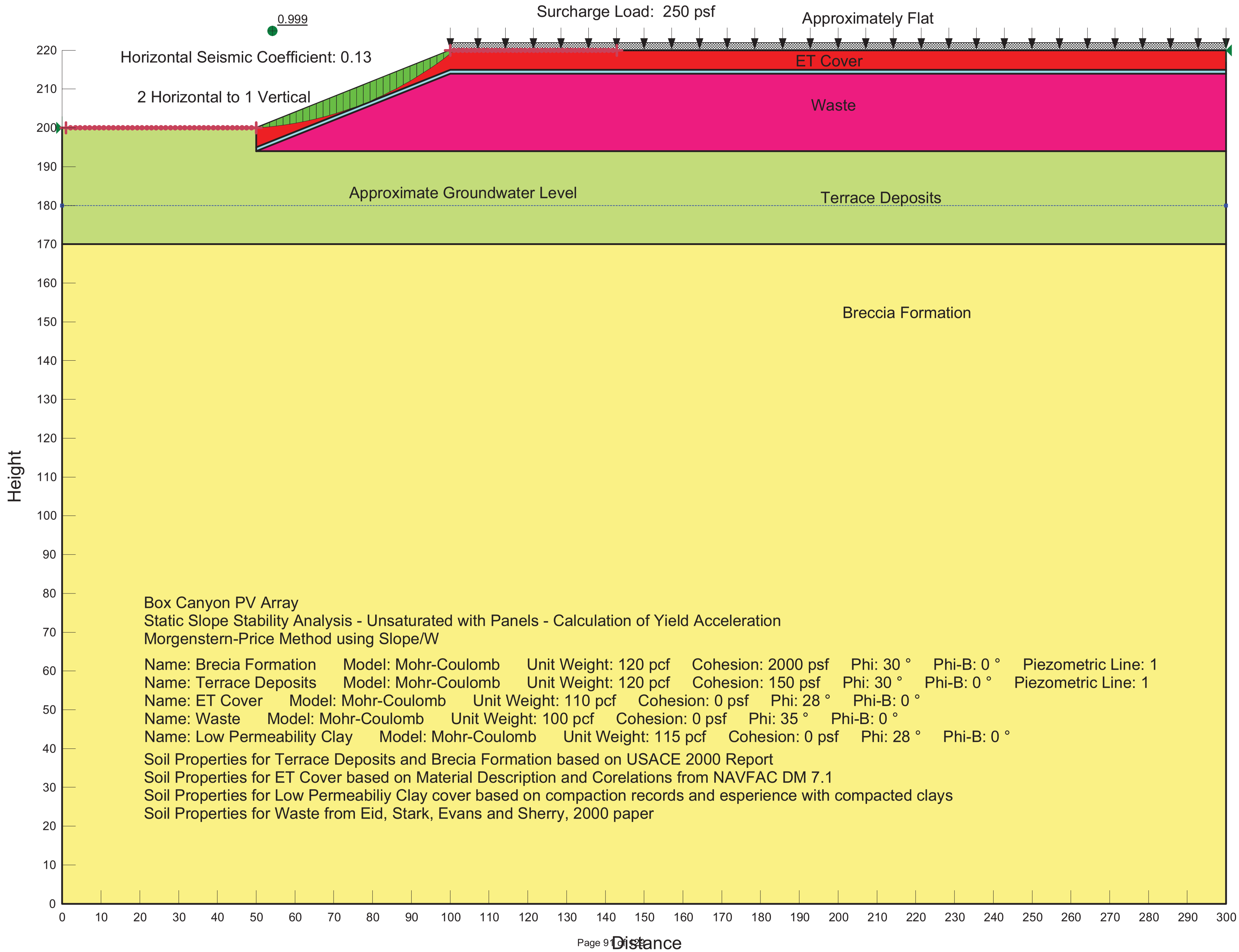
Critical Slip Surfaces

	Slip Surface	FOS	Center (ft)	Radius (ft)	Entry (ft)	Exit (ft)
1	18043	0.860	(43.669, 288.327)	88.554	(100, 220)	(50, 200)

Slices of Slip Surface: 18043

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
1	18043	50.833335	200.06765	0	28.513624	15.160963	0
2	18043	52.5	200.2188	0	85.431969	45.424984	0
3	18043	54.166665	200.4018	0	140.93511	74.936526	0
4	18043	55.833335	200.6169	0	194.07257	103.19022	0
5	18043	57.5	200.86425	0	243.77481	129.61736	0
6	18043	59.166665	201.14415	0	288.90107	153.61142	0
7	18043	60.833335	201.45695	0	328.41482	174.62126	0
8	18043	62.5	201.80295	0	361.4568	192.18999	0
9	18043	64.166665	202.1826	0	387.45667	206.01437	0
10	18043	65.833335	202.59635	0	406.19472	215.97757	0
11	18043	67.5	203.04465	0	417.80096	222.14871	0
12	18043	69.166665	203.52805	0	422.71851	224.76342	0
13	18043	70.833335	204.0472	0	421.65568	224.1983	0
14	18043	72.5	204.60275	0	415.47816	220.91366	0
15	18043	74.166665	205.19545	0	405.13586	215.41456	0
16	18043	75.833335	205.82605	0	391.53087	208.18066	0
17	18043	77.5	206.49545	0	375.49051	199.65185	0
18	18043	79.166665	207.20465	0	357.68665	190.18536	0
19	18043	80.833335	207.9546	0	338.61411	180.04432	0
20	18043	82.5	208.74655	0	318.58337	169.39378	0
21	18043	84.166665	209.58175	0	297.7177	158.29931	0
22	18043	85.833335	210.46155	0	275.98859	146.74573	0
23	18043	87.5	211.38755	0	253.21405	134.6363	0
24	18043	89.166665	212.3614	0	229.0749	121.80129	0
25	18043	90.833335	213.38495	0	203.14261	108.01284	0
26	18043	92.5	214.4603	0	174.88679	92.988958	0
27	18043	94.166665	215.5897	0	143.65629	76.383406	0

28	18043	95.833335	216.77575	0	108.71399	57.804255	0
29	18043	97.5	218.02135	0	69.200921	36.794783	0
30	18043	99.166665	219.3297	0	24.151633	12.841651	0


0.999
Surcharge Load: 250 psf
Approximately Flat
Horizontal Seismic Coefficient: 0.13
2 Horizontal to 1 Vertical
ET Cover
Waste
Approximate Groundwater Level
Terrace Deposits
Breccia Formation
Box Canyon PV Array
Static Slope Stability Analysis - Unsaturated with Panels - Calculation of Yield Acceleration
Morgenstern-Price Method using Slope/W
Name: Brecia Formation Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion: 2000 psf Phi: 30 ° Phi-B: 0 ° Piezometric Line: 1
Name: Terrace Deposits Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion: 150 psf Phi: 30 ° Phi-B: 0 ° Piezometric Line: 1
Name: ET Cover Model: Mohr-Coulomb Unit Weight: 110 pcf Cohesion: 0 psf Phi: 28 ° Phi-B: 0 °
Name: Waste Model: Mohr-Coulomb Unit Weight: 100 pcf Cohesion: 0 psf Phi: 35 ° Phi-B: 0 °
Name: Low Permeability Clay Model: Mohr-Coulomb Unit Weight: 115 pcf Cohesion: 0 psf Phi: 28 ° Phi-B: 0 °
Soil Properties for Terrace Deposits and Brecia Formation based on USACE 2000 Report
Soil Properties for ET Cover based on Material Description and Corelations from NAVFAC DM 7.1
Soil Properties for Low Permeabiliy Clay cover based on compaction records and esperience with compacted clays
Soil Properties for Waste from Eid, Stark, Evans and Sherry, 2000 paper
Height
Distance
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
220
230
240
250
260
270
280
290
300

SLOPE/W Analysis

File Information

Created By: Thomas, Jeremy
Revision Number: 39
Last Edited By: Thomas, Jeremy
Date: 6/2/2010
Time: 2:08:36 PM
File Name: Yield_panels_unsat.gsz
Directory: K:\PROJECTS\Camp Pendelton Solar Array\In_Progress\Revised Slpoe Stability\6-2-10 Revision\
Last Solved Date: 6/2/2010
Last Solved Time: 2:09:04 PM

Project Settings

Length(L) Units: feet
Time(t) Units: Seconds
Force(F) Units: lbf
Pressure(p) Units: psf
Strength Units: psf
Unit Weight of Water: 62.4 pcf
View: 2D

Analysis Settings

SLOPE/W Analysis

Kind: SLOPE/W
Method: Morgenstern-Price
Settings
- Apply Phreatic Correction: No
- Side Function
  - Interslice force function option: Half-Sine
- PWP Conditions Source: Piezometric Line
- Use Staged Rapid Drawdown: No

SlipSurface
- Direction of movement: Right to Left
- Use Passive Mode: No
- Slip Surface Option: Entry and Exit
- Critical slip surfaces saved: 1
- Optimize Critical Slip Surface Location: No
- Tension Crack

Tension Crack Option: (none)

FOS Distribution

FOS Calculation Option: Constant

Advanced

Number of Slices: 30

Optimization Tolerance: 0.01

Minimum Slip Surface Depth: 4 ft

Optimization Maximum Iterations: 2000

Optimization Convergence Tolerance: 1e-007

Starting Optimization Points: 8

Ending Optimization Points: 16

Complete Passes per Insertion: 1

Driving Side Maximum Convex Angle: 5 °

Resisting Side Maximum Convex Angle: 1 °

Materials

Brecia Formation

Model: Mohr-Coulomb

Unit Weight: 120 pcf

Cohesion: 2000 psf

Phi: 30 °

Phi-B: 0 °

Pore Water Pressure

Piezometric Line: 1

Terrace Deposits

Model: Mohr-Coulomb

Unit Weight: 120 pcf

Cohesion: 150 psf

Phi: 30 °

Phi-B: 0 °

Pore Water Pressure

Piezometric Line: 1

ET Cover

Model: Mohr-Coulomb

Unit Weight: 110 pcf

Cohesion: 0 psf

Phi: 28 °

Phi-B: 0 °

Waste

Model: Mohr-Coulomb

Unit Weight: 100 pcf

Cohesion: 0 psf

Phi: 35 °
Phi-B: 0 °

Low Permeability Clay

Model: Mohr-Coulomb
Unit Weight: 115 pcf
Cohesion: 0 psf
Phi: 28 °
Phi-B: 0 °

Slip Surface Entry and Exit

Left Projection: Range
Left-Zone Left Coordinate: (0.96082, 200) ft
Left-Zone Right Coordinate: (50, 200) ft
Left-Zone Increment: 40
Right Projection: Range
Right-Zone Left Coordinate: (100, 220) ft
Right-Zone Right Coordinate: (143, 220) ft
Right-Zone Increment: 40
Radius Increments: 10

Slip Surface Limits

Left Coordinate: (0, 200) ft
Right Coordinate: (300, 220) ft

Piezometric Lines

Piezometric Line 1

Coordinates

	X (ft)	Y (ft)
	0	180
	300	180

Surcharge Loads

Surcharge Load 1

Surcharge (Unit Weight): 125 pcf
Direction: Vertical

Coordinates

	X (ft)	Y (ft)
	100	222
	300	222

Seismic Loads

Horz Seismic Load: 0.13
Ignore seismic load in strength: No

Regions

	Material	Points	Area (ft²)
Region 1	Brecia Formation	1,2,11,10	51000
Region 2	Terrace Deposits	2,3,4,15,7,12,11	7500
Region 3	Waste	7,8,9,12	4500
Region 4	Low Permeability Clay	7,8,9,13,14,15	250
Region 5	ET Cover	15,4,5,6,13,14	1250

Points

	X (ft)	Y (ft)
Point 1	0	0
Point 2	0	170
Point 3	0	200
Point 4	50	200
Point 5	100	220
Point 6	300	220
Point 7	50	194
Point 8	100	214
Point 9	300	214
Point 10	300	0
Point 11	300	170
Point 12	300	194
Point 13	300	215
Point 14	100	215
Point 15	50	195

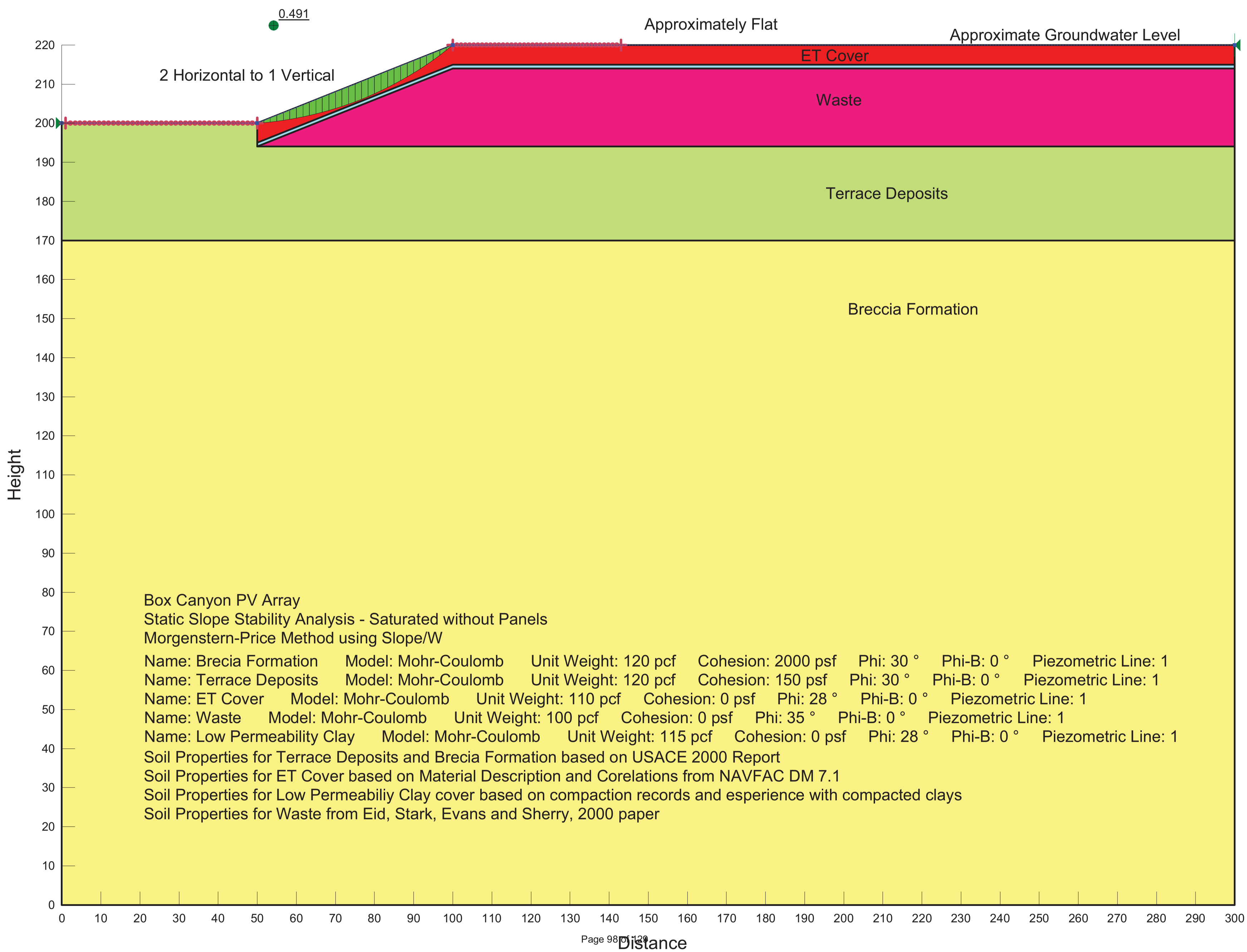
Critical Slip Surfaces

	Slip Surface	FOS	Center (ft)	Radius (ft)	Entry (ft)	Exit (ft)
1	18054	0.999	(44.463, 289.356)	89.527	(101.075, 220)	(50, 200)

Slices of Slip Surface: 18054

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
1	18054	50.86207	200.0618	0	30.663113	16.303866	0
2	18054	52.58621	200.2021	0	91.735594	48.776681	0
3	18054	54.310345	200.376	0	151.05519	80.317469	0
4	18054	56.03448	200.5838	0	207.6524	110.41074	0
5	18054	57.75862	200.82565	0	260.47435	138.49667	0
6	18054	59.48276	201.1018	0	308.45752	164.00977	0
7	18054	61.2069	201.41265	0	350.64489	186.44119	0
8	18054	62.931035	201.75855	0	386.27998	205.38871	0
9	18054	64.65517	202.1399	0	414.87968	220.59544	0
10	18054	66.37931	202.55715	0	436.26648	231.967	0
11	18054	68.10345	203.0108	0	450.56168	239.56789	0
12	18054	69.82759	203.5015	0	458.16375	243.60999	0
13	18054	71.551725	204.0299	0	459.68961	244.4213	0
14	18054	73.27586	204.59665	0	455.88985	242.40093	0
15	18054	75	205.2025	0	447.57737	237.98111	0
16	18054	76.72414	205.84835	0	435.56193	231.59239	0
17	18054	78.448275	206.53515	0	420.57231	223.62226	0
18	18054	80.17241	207.2639	0	403.21924	214.39548	0
19	18054	81.89655	208.0357	0	383.98639	204.16919	0
20	18054	83.62069	208.8518	0	363.18715	193.11003	0
21	18054	85.34483	209.71365	0	340.99751	181.31159	0
22	18054	87.068965	210.6227	0	317.43635	168.7839	0
23	18054	88.7931	211.58055	0	292.38098	155.46173	0
24	18054	90.51724	212.58905	0	265.56723	141.2046	0
25	18054	92.24138	213.65025	0	236.62646	125.81652	0
26	18054	93.96552	214.76645	0	205.04164	109.02257	0

27	18054	95.689655	215.9401	0	170.17518	90.483748	0
28	18054	97.41379	217.174	0	131.27275	69.79896	0
29	18054	99.13793	218.4713	0	87.419773	46.481918	0
30	18054	100.5375	219.5681	0	206.50142	109.79875	0


0.491
Approximately Flat
Approximate Groundwater Level
2 Horizontal to 1 Vertical
ET Cover
Waste
Terrace Deposits
Breccia Formation
Box Canyon PV Array
Static Slope Stability Analysis - Saturated without Panels
Morgenstern-Price Method using Slope/W
Name: Brecia Formation Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion: 2000 psf Phi: 30 ° Phi-B: 0 ° Piezometric Line: 1
Name: Terrace Deposits Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion: 150 psf Phi: 30 ° Phi-B: 0 ° Piezometric Line: 1
Name: ET Cover Model: Mohr-Coulomb Unit Weight: 110 pcf Cohesion: 0 psf Phi: 28 ° Phi-B: 0 ° Piezometric Line: 1
Name: Waste Model: Mohr-Coulomb Unit Weight: 100 pcf Cohesion: 0 psf Phi: 35 ° Phi-B: 0 ° Piezometric Line: 1
Name: Low Permeability Clay Model: Mohr-Coulomb Unit Weight: 115 pcf Cohesion: 0 psf Phi: 28 ° Phi-B: 0 ° Piezometric Line: 1
Soil Properties for Terrace Deposits and Brecia Formation based on USACE 2000 Report
Soil Properties for ET Cover based on Material Description and Corelations from NAVFAC DM 7.1
Soil Properties for Low Permeabiliy Clay cover based on compaction records and esperience with compacted clays
Soil Properties for Waste from Eid, Stark, Evans and Sherry, 2000 paper
Height
Distance

SLOPE/W Analysis

File Information

Created By: Thomas, Jeremy
Revision Number: 37
Last Edited By: Thomas, Jeremy
Date: 6/2/2010
Time: 4:52:02 PM
File Name: Static_panels_sat.gsz
Directory: K:\PROJECTS\Camp Pendelton Solar Array\In_Progress\Revised Slpoe Stability\6-2-10 Revision\
Last Solved Date: 6/2/2010
Last Solved Time: 4:52:31 PM

Project Settings

Length(L) Units: feet
Time(t) Units: Seconds
Force(F) Units: lbf
Pressure(p) Units: psf
Strength Units: psf
Unit Weight of Water: 62.4 pcf
View: 2D

Analysis Settings

SLOPE/W Analysis

Kind: SLOPE/W
Method: Morgenstern-Price
Settings
- Apply Phreatic Correction: No
- Side Function
  - Interslice force function option: Half-Sine
- PWP Conditions Source: Piezometric Line
- Use Staged Rapid Drawdown: No

SlipSurface
- Direction of movement: Right to Left
- Use Passive Mode: No
- Slip Surface Option: Entry and Exit
- Critical slip surfaces saved: 1
- Optimize Critical Slip Surface Location: No
- Tension Crack

Tension Crack Option: (none)
FOS Distribution
FOS Calculation Option: Constant
Advanced
Number of Slices: 30
Optimization Tolerance: 0.01
Minimum Slip Surface Depth: 4 ft
Optimization Maximum Iterations: 2000
Optimization Convergence Tolerance: 1e-007
Starting Optimization Points: 8
Ending Optimization Points: 16
Complete Passes per Insertion: 1
Driving Side Maximum Convex Angle: 5 °
Resisting Side Maximum Convex Angle: 1 °

Materials

Brecia Formation

Model: Mohr-Coulomb
Unit Weight: 120 pcf
Cohesion: 2000 psf
Phi: 30 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

Terrace Deposits

Model: Mohr-Coulomb
Unit Weight: 120 pcf
Cohesion: 150 psf
Phi: 30 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

ET Cover

Model: Mohr-Coulomb
Unit Weight: 110 pcf
Cohesion: 0 psf
Phi: 28 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

Waste

Model: Mohr-Coulomb

Unit Weight: 100 pcf
Cohesion: 0 psf
Phi: 35 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

Low Permeability Clay

Model: Mohr-Coulomb
Unit Weight: 115 pcf
Cohesion: 0 psf
Phi: 28 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

Slip Surface Entry and Exit

Left Projection: Range
Left-Zone Left Coordinate: (0.96082, 200) ft
Left-Zone Right Coordinate: (50, 200) ft
Left-Zone Increment: 40
Right Projection: Range
Right-Zone Left Coordinate: (100, 220) ft
Right-Zone Right Coordinate: (143, 220) ft
Right-Zone Increment: 40
Radius Increments: 10

Slip Surface Limits

Left Coordinate: (0, 200) ft
Right Coordinate: (300, 220) ft

Piezometric Lines

Piezometric Line 1

Coordinates

	X (ft)	Y (ft)
	0	200
	50	200
	100	220
	300	220

Surcharge Loads

Surcharge Load 1

Surcharge (Unit Weight): 125 pcf
Direction: Vertical

Coordinates

	X (ft)	Y (ft)
	100	222
	300	222

Regions

	Material	Points	Area (ft^2)
Region 1	Brecia Formation	1,2,11,10	51000
Region 2	Terrace Deposits	2,3,4,15,7,12,11	7500
Region 3	Waste	7,8,9,12	4500
Region 4	Low Permeability Clay	7,8,9,13,14,15	250
Region 5	ET Cover	15,4,5,6,13,14	1250

Points

	X (ft)	Y (ft)
Point 1	0	0
Point 2	0	170
Point 3	0	200
Point 4	50	200
Point 5	100	220
Point 6	300	220
Point 7	50	194
Point 8	100	214
Point 9	300	214
Point 10	300	0
Point 11	300	170
Point 12	300	194
Point 13	300	215
Point 14	100	215

Point 15	50	195

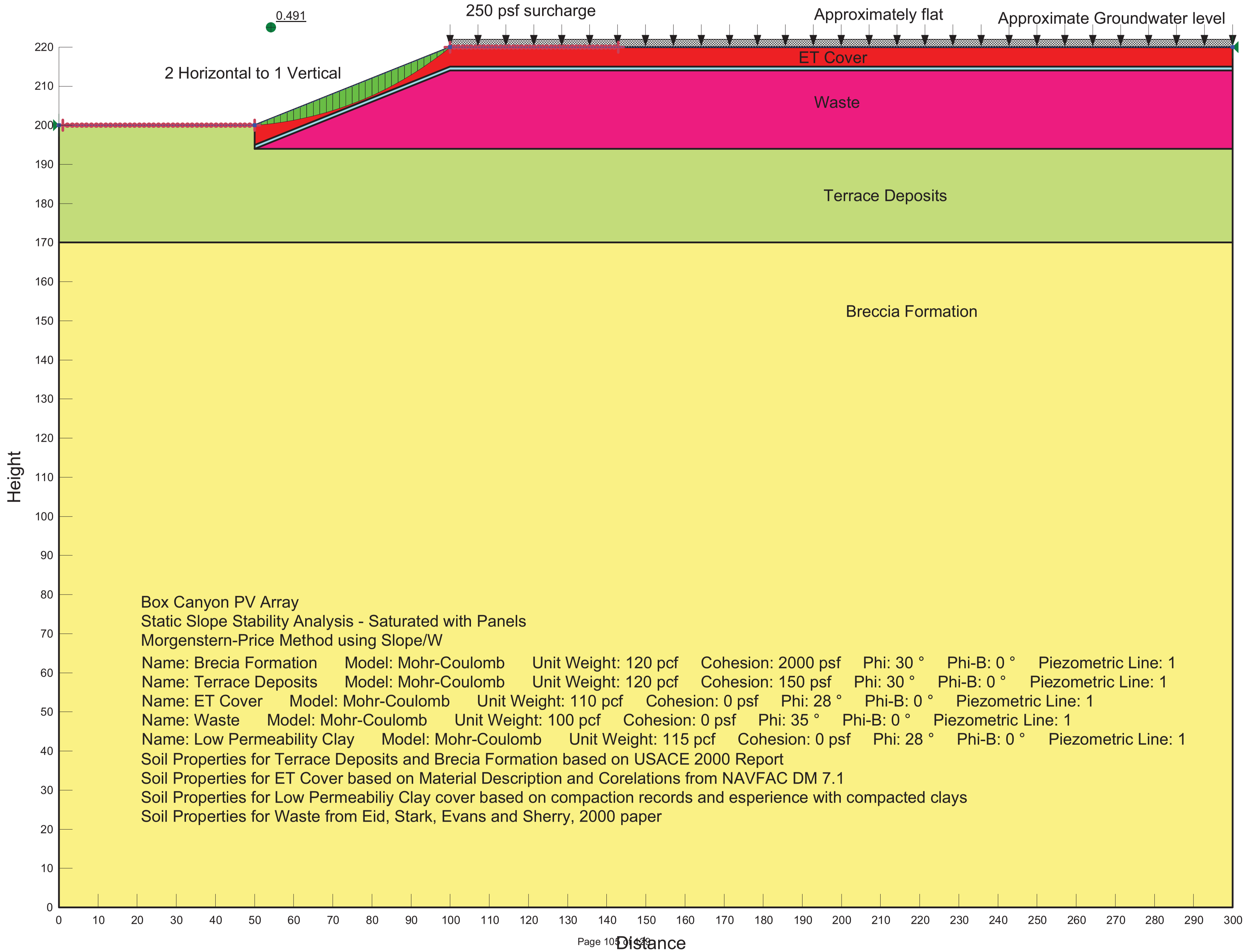
Critical Slip Surfaces

	Slip Surface	FOS	Center (ft)	Radius (ft)	Entry (ft)	Exit (ft)
1	18043	0.491	(43.669, 288.327)	88.554	(100, 220)	(50, 200)

Slices of Slip Surface: 18043

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
1	18043	50.833335	200.06765	16.579274	28.462792	6.3185783	0
2	18043	52.5	200.2188	48.746371	83.963327	18.725188	0
3	18043	54.166665	200.4018	78.927473	136.37152	30.54354	0
4	18043	55.833335	200.6169	107.1069	185.34213	41.598408	0
5	18043	57.5	200.86425	133.27194	230.54125	51.719011	0
6	18043	59.166665	201.14415	157.4025	271.62785	60.7347	0
7	18043	60.833335	201.45695	179.48799	308.31344	68.497703	0
8	18043	62.5	201.80295	199.49803	340.38604	74.911483	0
9	18043	64.166665	202.1826	217.40628	367.68079	79.902377	0
10	18043	65.833335	202.59635	233.19092	390.16187	83.462936	0
11	18043	67.5	203.04465	246.81698	407.85594	85.62593	0
12	18043	69.166665	203.52805	258.2485	420.87983	86.472615	0
13	18043	70.833335	204.0472	267.4552	429.42795	86.12244	0
14	18043	72.5	204.60275	274.38907	433.73408	84.725245	0
15	18043	74.166665	205.19545	279.00372	434.06649	82.44834	0
16	18043	75.833335	205.82605	281.25332	430.69011	79.45695	0
17	18043	77.5	206.49545	281.08419	423.85254	75.911276	0
18	18043	79.166665	207.20465	278.43403	413.77032	71.959581	0
19	18043	80.833335	207.9546	273.23523	400.5947	67.71823	0
20	18043	82.5	208.74655	265.41515	384.42893	63.280754	0
21	18043	84.166665	209.58175	254.89847	365.28404	58.693049	0
22	18043	85.833335	210.46155	241.59883	343.12194	53.980795	0
23	18043	87.5	211.38755	225.41629	317.8183	49.131023	0
24	18043	89.166665	212.3614	206.25132	289.18628	44.097304	0
25	18043	90.833335	213.38495	183.97802	256.96494	38.807833	0

26	18043	92.5	214.4603	158.47974	220.85458	33.16529	0
27	18043	94.166665	215.5897	129.60462	180.47355	27.047488	0
28	18043	95.833335	216.77575	97.189523	135.41857	20.326743	0
29	18043	97.5	218.02135	61.06412	85.226799	12.847524	0
30	18043	99.166665	219.3297	21.025731	29.395442	4.4502543	0


0.491
250 psf surcharge
Approximately flat
Approximate Groundwater level
2 Horizontal to 1 Vertical
ET Cover
Waste
Terrace Deposits
Breccia Formation
Box Canyon PV Array
Static Slope Stability Analysis - Saturated with Panels
Morgenstern-Price Method using Slope/W
Name: Brecia Formation Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion: 2000 psf Phi: 30 ° Phi-B: 0 ° Piezometric Line: 1
Name: Terrace Deposits Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion: 150 psf Phi: 30 ° Phi-B: 0 ° Piezometric Line: 1
Name: ET Cover Model: Mohr-Coulomb Unit Weight: 110 pcf Cohesion: 0 psf Phi: 28 ° Phi-B: 0 ° Piezometric Line: 1
Name: Waste Model: Mohr-Coulomb Unit Weight: 100 pcf Cohesion: 0 psf Phi: 35 ° Phi-B: 0 ° Piezometric Line: 1
Name: Low Permeability Clay Model: Mohr-Coulomb Unit Weight: 115 pcf Cohesion: 0 psf Phi: 28 ° Phi-B: 0 ° Piezometric Line: 1
Soil Properties for Terrace Deposits and Brecia Formation based on USACE 2000 Report
Soil Properties for ET Cover based on Material Description and Corelations from NAVFAC DM 7.1
Soil Properties for Low Permeabiliy Clay cover based on compaction records and esperience with compacted clays
Soil Properties for Waste from Eid, Stark, Evans and Sherry, 2000 paper
Height
Distance
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
220
230
240
250
260
270
280
290
300

SLOPE/W Analysis

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File Information

Created By: Thomas, Jeremy
Revision Number: 37
Last Edited By: Thomas, Jeremy
Date: 6/2/2010
Time: 4:52:02 PM
File Name: Static_panels_sat.gsz
Directory: K:\PROJECTS\Camp Pendelton Solar Array\In_Progress\Revised Slpoe Stability\6-2-10 Revision\
Last Solved Date: 6/2/2010
Last Solved Time: 4:52:31 PM

Project Settings

Length(L) Units: feet
Time(t) Units: Seconds
Force(F) Units: lbf
Pressure(p) Units: psf
Strength Units: psf
Unit Weight of Water: 62.4 pcf
View: 2D

Analysis Settings

SLOPE/W Analysis

Kind: SLOPE/W
Method: Morgenstern-Price
Settings
- Apply Phreatic Correction: No
- Side Function
  - Interslice force function option: Half-Sine
- PWP Conditions Source: Piezometric Line
- Use Staged Rapid Drawdown: No

SlipSurface
- Direction of movement: Right to Left
- Use Passive Mode: No
- Slip Surface Option: Entry and Exit
- Critical slip surfaces saved: 1
- Optimize Critical Slip Surface Location: No
- Tension Crack

Tension Crack Option: (none)

FOS Distribution

FOS Calculation Option: Constant

Advanced

Number of Slices: 30

Optimization Tolerance: 0.01

Minimum Slip Surface Depth: 4 ft

Optimization Maximum Iterations: 2000

Optimization Convergence Tolerance: 1e-007

Starting Optimization Points: 8

Ending Optimization Points: 16

Complete Passes per Insertion: 1

Driving Side Maximum Convex Angle: 5 °

Resisting Side Maximum Convex Angle: 1 °

Materials

Brecia Formation

Model: Mohr-Coulomb

Unit Weight: 120 pcf

Cohesion: 2000 psf

Phi: 30 °

Phi-B: 0 °

Pore Water Pressure

Piezometric Line: 1

Terrace Deposits

Model: Mohr-Coulomb

Unit Weight: 120 pcf

Cohesion: 150 psf

Phi: 30 °

Phi-B: 0 °

Pore Water Pressure

Piezometric Line: 1

ET Cover

Model: Mohr-Coulomb

Unit Weight: 110 pcf

Cohesion: 0 psf

Phi: 28 °

Phi-B: 0 °

Pore Water Pressure

Piezometric Line: 1

Waste

Model: Mohr-Coulomb

Unit Weight: 100 pcf
Cohesion: 0 psf
Phi: 35 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

Low Permeability Clay

Model: Mohr-Coulomb
Unit Weight: 115 pcf
Cohesion: 0 psf
Phi: 28 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

Slip Surface Entry and Exit

Left Projection: Range
Left-Zone Left Coordinate: (0.96082, 200) ft
Left-Zone Right Coordinate: (50, 200) ft
Left-Zone Increment: 40
Right Projection: Range
Right-Zone Left Coordinate: (100, 220) ft
Right-Zone Right Coordinate: (143, 220) ft
Right-Zone Increment: 40
Radius Increments: 10

Slip Surface Limits

Left Coordinate: (0, 200) ft
Right Coordinate: (300, 220) ft

Piezometric Lines

Piezometric Line 1

Coordinates

	X (ft)	Y (ft)
	0	200
	50	200
	100	220
	300	220

Surcharge Loads

Surcharge Load 1

Surcharge (Unit Weight): 125 pcf
Direction: Vertical

Coordinates

	X (ft)	Y (ft)
	100	222
	300	222

Regions

	Material	Points	Area (ft^2)
Region 1	Brecia Formation	1,2,11,10	51000
Region 2	Terrace Deposits	2,3,4,15,7,12,11	7500
Region 3	Waste	7,8,9,12	4500
Region 4	Low Permeability Clay	7,8,9,13,14,15	250
Region 5	ET Cover	15,4,5,6,13,14	1250

Points

	X (ft)	Y (ft)
Point 1	0	0
Point 2	0	170
Point 3	0	200
Point 4	50	200
Point 5	100	220
Point 6	300	220
Point 7	50	194
Point 8	100	214
Point 9	300	214
Point 10	300	0
Point 11	300	170
Point 12	300	194
Point 13	300	215
Point 14	100	215

Point 15	50	195

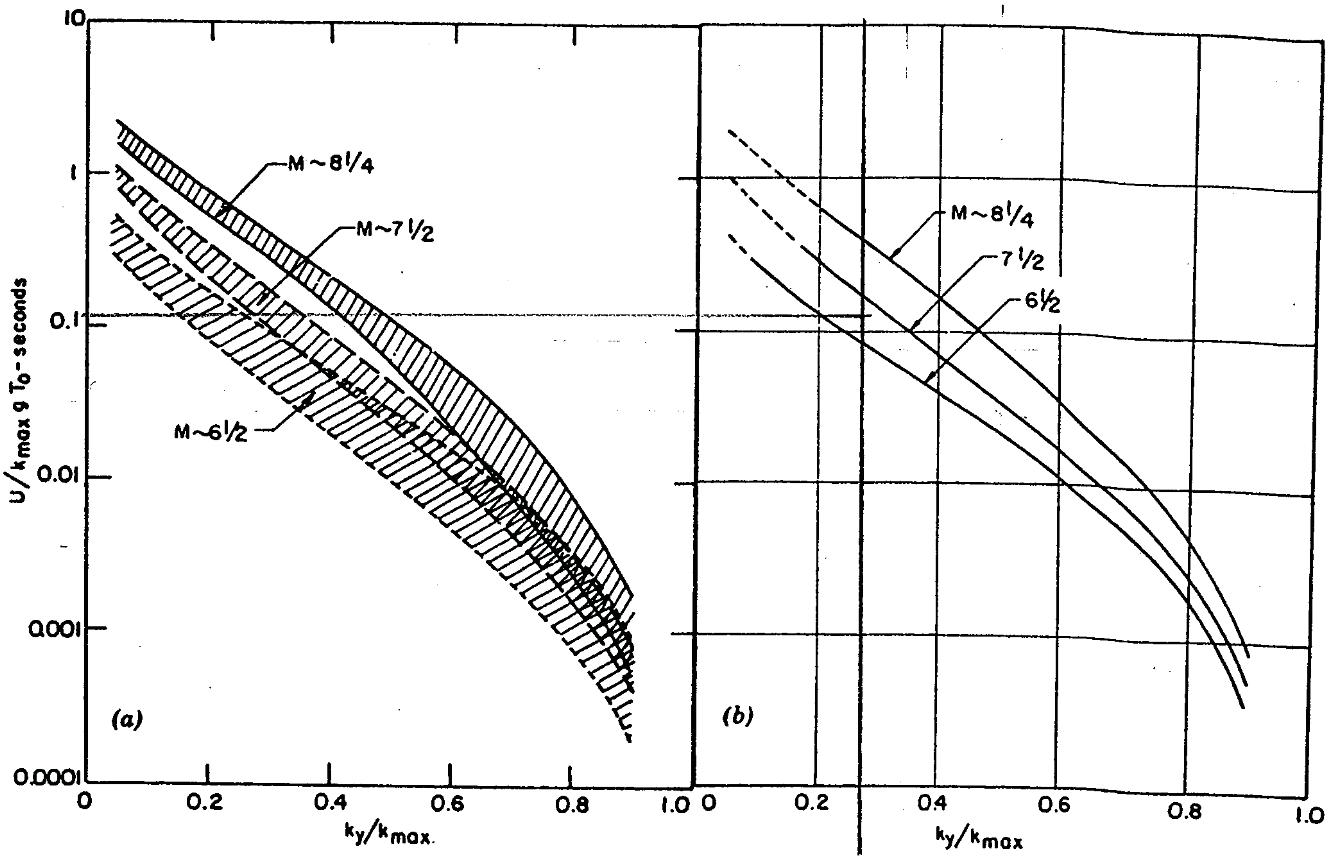
Critical Slip Surfaces

	Slip Surface	FOS	Center (ft)	Radius (ft)	Entry (ft)	Exit (ft)
1	18043	0.491	(43.669, 288.327)	88.554	(100, 220)	(50, 200)

Slices of Slip Surface: 18043

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
1	18043	50.833335	200.06765	16.579274	28.462792	6.3185783	0
2	18043	52.5	200.2188	48.746371	83.963327	18.725188	0
3	18043	54.166665	200.4018	78.927473	136.37152	30.54354	0
4	18043	55.833335	200.6169	107.1069	185.34213	41.598408	0
5	18043	57.5	200.86425	133.27194	230.54125	51.719011	0
6	18043	59.166665	201.14415	157.4025	271.62785	60.7347	0
7	18043	60.833335	201.45695	179.48799	308.31344	68.497703	0
8	18043	62.5	201.80295	199.49803	340.38604	74.911483	0
9	18043	64.166665	202.1826	217.40628	367.68079	79.902377	0
10	18043	65.833335	202.59635	233.19092	390.16187	83.462936	0
11	18043	67.5	203.04465	246.81698	407.85594	85.62593	0
12	18043	69.166665	203.52805	258.2485	420.87983	86.472615	0
13	18043	70.833335	204.0472	267.4552	429.42795	86.12244	0
14	18043	72.5	204.60275	274.38907	433.73408	84.725245	0
15	18043	74.166665	205.19545	279.00372	434.06649	82.44834	0
16	18043	75.833335	205.82605	281.25332	430.69011	79.45695	0
17	18043	77.5	206.49545	281.08419	423.85254	75.911276	0
18	18043	79.166665	207.20465	278.43403	413.77032	71.959581	0
19	18043	80.833335	207.9546	273.23523	400.5947	67.71823	0
20	18043	82.5	208.74655	265.41515	384.42893	63.280754	0
21	18043	84.166665	209.58175	254.89847	365.28404	58.693049	0
22	18043	85.833335	210.46155	241.59883	343.12194	53.980795	0
23	18043	87.5	211.38755	225.41629	317.8183	49.131023	0
24	18043	89.166665	212.3614	206.25132	289.18628	44.097304	0
25	18043	90.833335	213.38495	183.97802	256.96494	38.807833	0

26	18043	92.5	214.4603	158.47974	220.85458	33.16529	0
27	18043	94.166665	215.5897	129.60462	180.47355	27.047488	0
28	18043	95.833335	216.77575	97.189523	135.41857	20.326743	0
29	18043	97.5	218.02135	61.06412	85.226799	12.847524	0
30	18043	99.166665	219.3297	21.025731	29.395442	4.4502543	0



0,265

FIG. 11.—Variation of Yield Acceleration with: (*a*) Normalized Permanent Dis ment—Summary of All Data; and (*b*) Average Normalized Displacement

magnitude earthquakes. At yield acceleration ratios less than 0.2 the av curves are shown as dashed lines since, as mentioned earlier, the calc displacements at these low ratios may be unrealistic.

Thus, to calculate the permanent deformation in an embankment const of a soil that does not change in strength significantly during an earthq it is sufficient to determine its maximum crest acceleration, $\ddot{u}_{max}$, and natural period, T_0, due to a specified earthquake. Then by the use o relationship presented in Fig. 7, the maximum value of average accele history, k_{max}, for any level of the specified sliding mass may be detern Entering the curves in Fig. 11(*b*) with the appropriate values of k_{max} an the permanent displacements can be determined for any value of yield accele associated with that particular sliding surface.

It has been assumed earlier in this paper that in the majority of embankm permanent deformations usually occur due to slip of a sliding mass on a horiz failure plane. For those few instances where sliding might occur on an inc

$$\rho(\ddot{u}+\ddot{u}_b) = \frac{1}{z}\frac{\partial}{\partial z}\left[\bar{G}(z)z\frac{\partial u}{\partial z}\right] \tag{7.61}$$

where the average shear modulus, $\bar{G}$, is given by

$$\bar{G}(z) = \frac{1}{x_u + x_d}\int_{-x_u}^{x_d} G(x, z)\, dx$$

Equation (7.62) is simply a one-dimensional wave equation (i.e., the shear beam approach allows the two-dimensional dam section to be represented as a one-dimensional system).

Gazetas (1982) developed solutions to the shear beam wave equation for the case where the shear modulus increases as a power function of depth according to $G(z) = G_b(z/H)^m$, where G_b is the average shear modulus at the base of the dam. For such conditions, the nth natural circular frequency (assuming $h/H = 1$) is given by

$$\omega_n = \frac{\bar{v}_{s,s}}{H}\frac{\beta_n}{8}(4+m)(2-m) \tag{7.62}$$

where $\bar{v}_{s,s}$ is the average shear wave velocity of the soil in the dam and β_n is the nth root of a period relation (Dakoulas and Gazetas, 1985) tabulated in Table 7-2 for the first five modes of vibration.

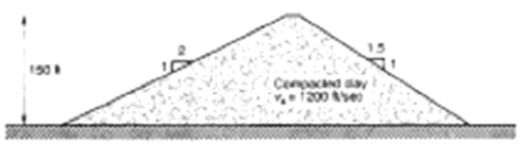


Figure E7.6

Table 7-2 Values of β_n for First Five Modes of Vibration of an Earth Dam

	n				
m	1	2	3	4	5
0	2.404	5.520	8.654	11.792	14.931
$\frac{1}{2}$	2.903	6.033	9.171	12.310	15.451
$\frac{4}{7}$	2.999	6.133	9.273	12.413	15.544
$\frac{2}{3}$	3.142	6.283	9.525	12.566	15.708
1	3.382	7.106	10.174	13.324	16.471

Equation (7.62) produces a fundamental period of

$$T_1 = \frac{16\pi}{(4+m)(2-m)\beta_1}\frac{H}{\bar{v}_{s,s}} \tag{7.63}$$

Example 7.6

The earth dam shown in Figure E 7.6 is constructed of compacted clay with a shear wave velocity of 1200 ft/sec. Compute the first three natural frequencies of the dam.

Solution Because the crest of the dam is so narrow, H ≈ h. Then, from equation (7.62), the first three natural frequencies can be calculated as

$$\omega_1 = \frac{\bar{v}_{s,s}}{H}\frac{\beta_1}{8}(4+m)(2-m) = \frac{1200}{150}\frac{2.404}{8}(4)(2) = 19.2 \text{ rad/sec} \qquad f_1 = 3.1 \text{ Hz}$$

$$\omega_2 = \frac{\bar{v}_{s,s}}{H}\frac{\beta_2}{8}(4+m)(2-m) = \frac{1200}{150}\frac{5.520}{8}(4)(2) = 44.2 \text{ rad/sec} \qquad f_2 = 7.0 \text{ Hz}$$

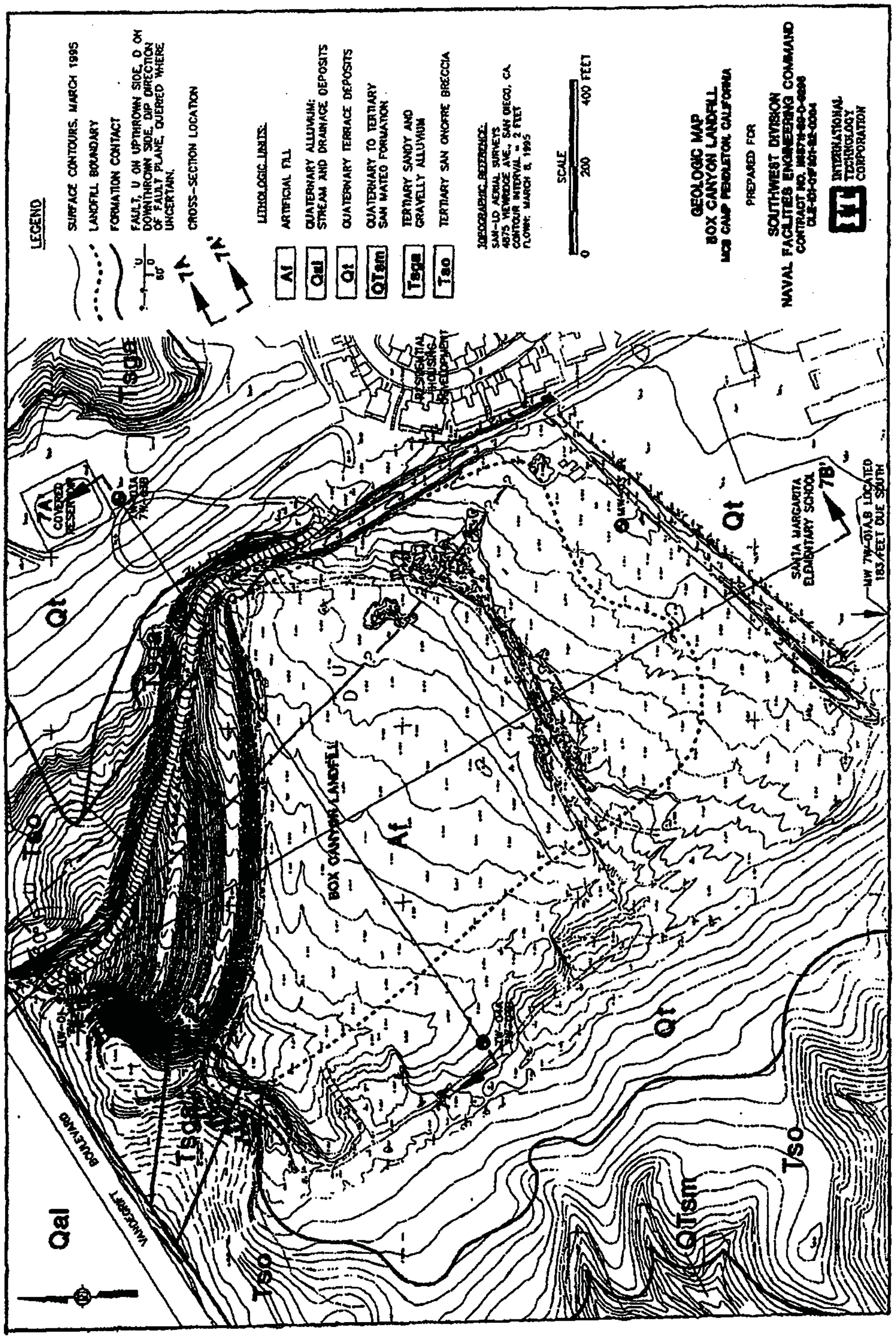


Figure 4 Geologic Map, Box Canyon Landfill

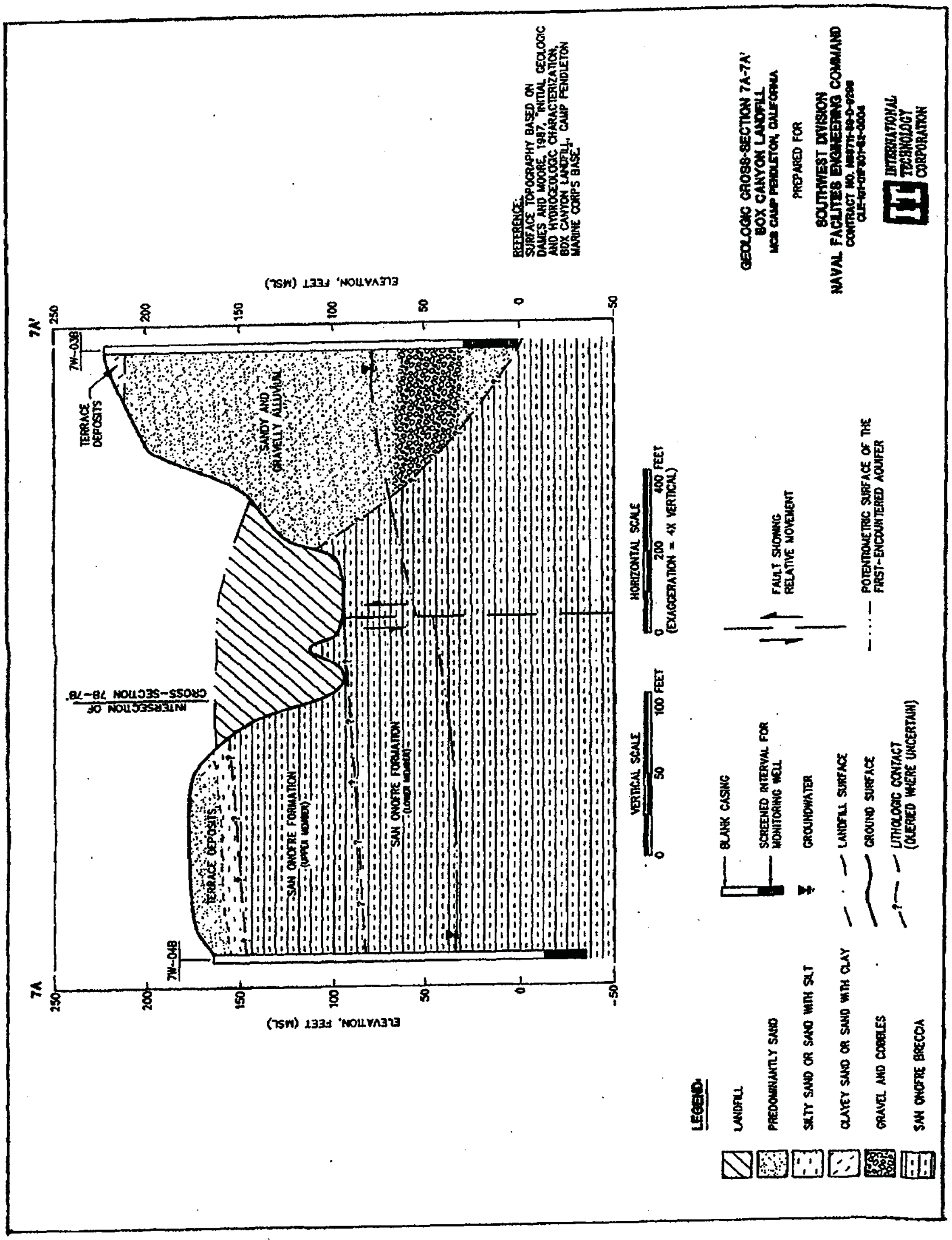


Figure 5 Geologic Cross Section 7A-7A'

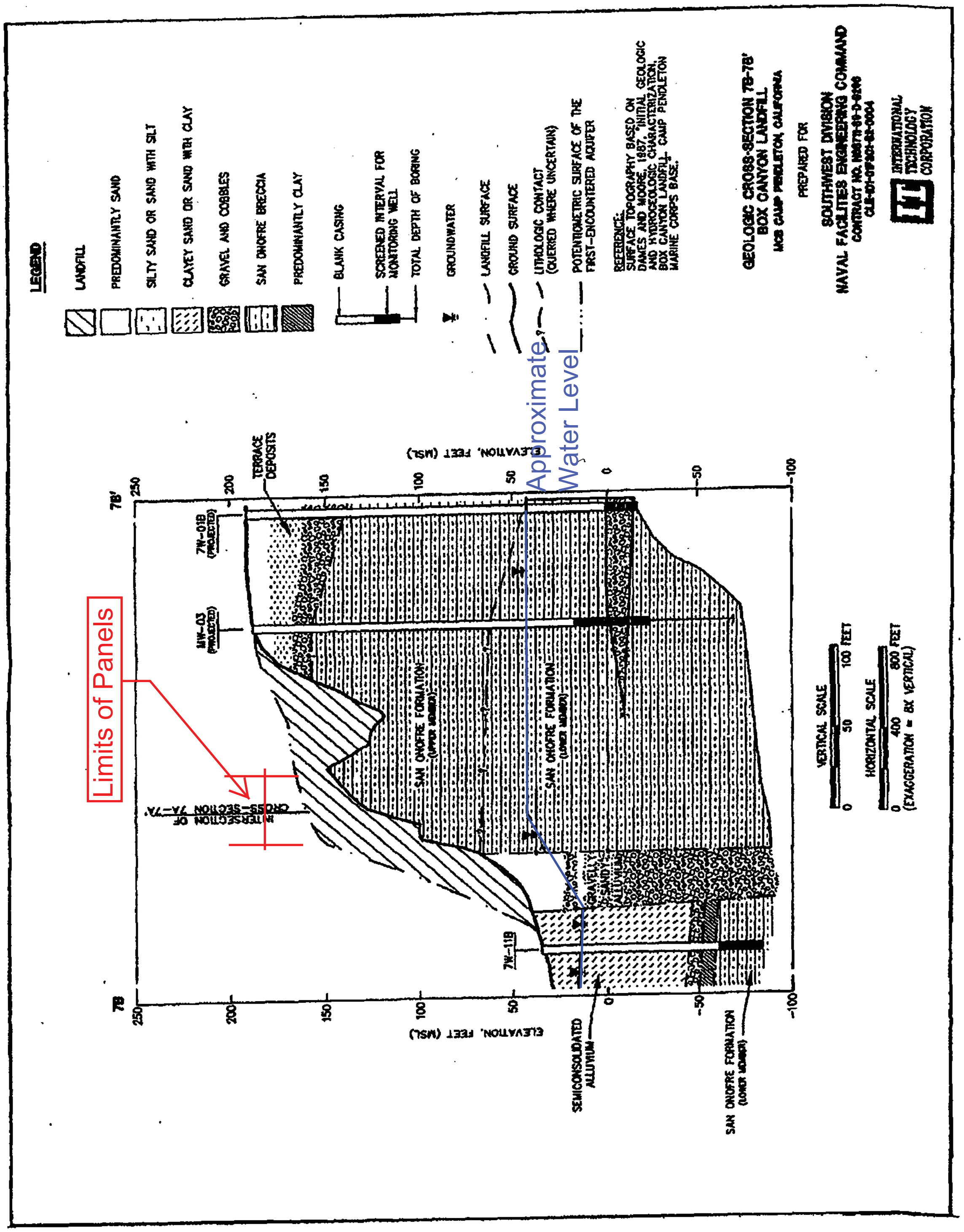
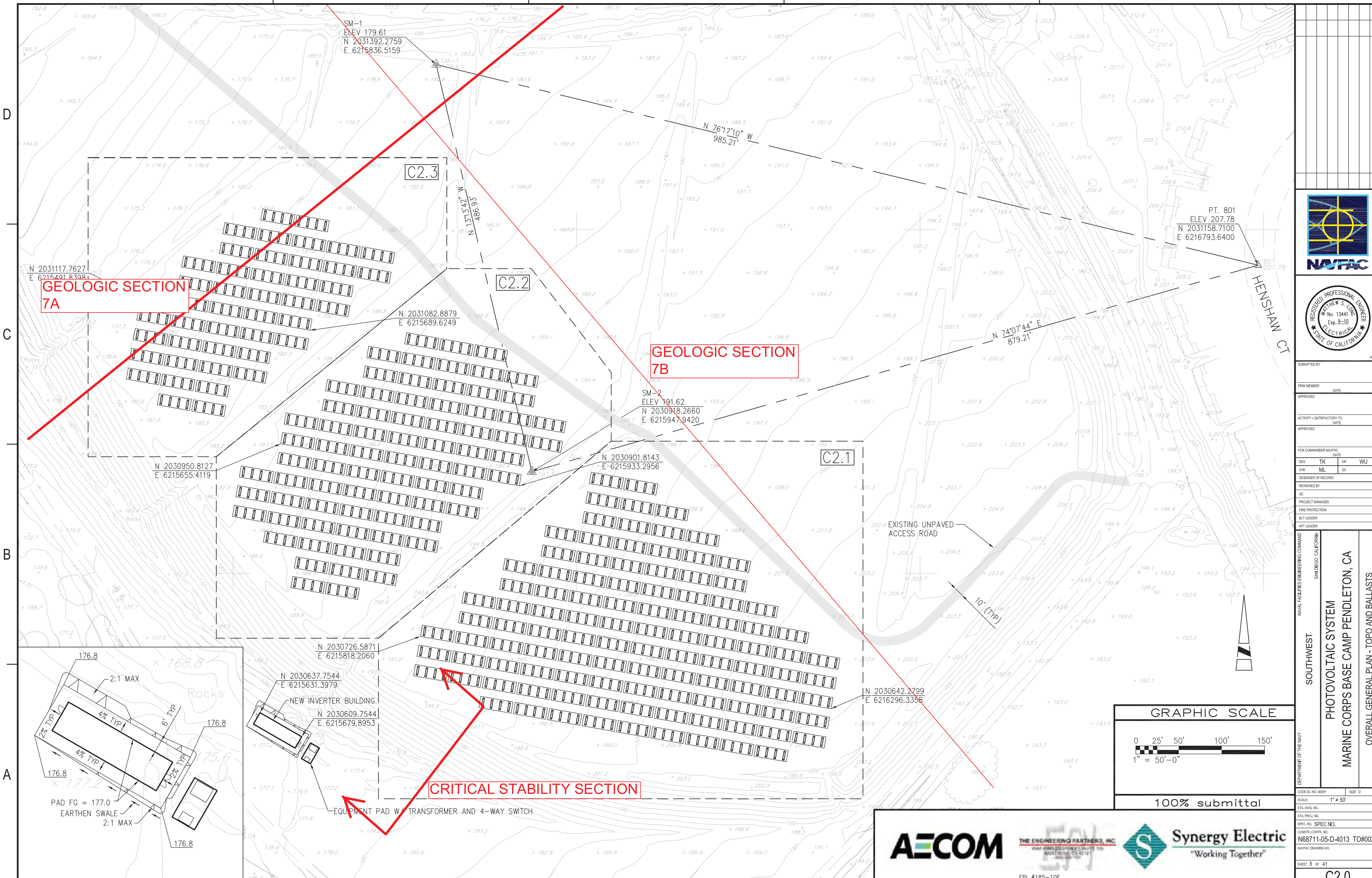


Figure 6 Geologic Cross Section 7B-7B'

1-19


GEOLOGIC SECTION 7A
GEOLOGIC SECTION 7B
CRITICAL STABILITY SECTION
C2.1
C2.2
C2.3
SM-1
ELEV 179.61
N 2031392.2759
E 6215836.5159
SM-2
ELEV 191.62
N 2030918.2660
E 6215947.9420
PT. 801
ELEV 207.78
N 2031158.7100
E 6216793.6400
N 76°17'10" W
985.21'
N 74°07'44" E
879.21'
N 13°13'42" W
486.93'
HENSHAW CT
N 2031117.7627
E 6215491.8398
N 2031082.8879
E 6215689.6249
N 2030950.8127
E 6215655.4119
N 2030901.8143
E 6215933.2956
N 2030726.5871
E 6215818.2060
N 2030637.7544
E 6215631.3979
NEW INVERTER BUILDING
N 2030609.7544
E 6215679.8953
N 2030642.2799
E 6216296.3358
EQUIPMENT PAD W/ TRANSFORMER AND 4-WAY SWITCH
EXISTING UNPAVED ACCESS ROAD
10' (TYP)
176.8
2:1 MAX
6' TYP
2% TYP
4% TYP
PAD FG = 177.0
EARTHEN SWALE
GRAPHIC SCALE
0 25' 50' 100' 150'
1" = 50'-0"
100% submittal
AECOM
THE ENGINEERING PARTNERS, INC
EPI #185-10E
Synergy Electric
"Working Together"
NAVFAC
REGISTERED PROFESSIONAL ENGINEER
MATTHEW S. LONG
No. 13441
Exp. 9-10
ELECTRICAL
STATE OF CALIFORNIA
SUBMITTED BY
FIRM MEMBER
DATE
APPROVED
ACTIVITY • SATISFACTORY TO
FOR COMMANDER NAVFAC
DES TK
DR WU
CHK ML
DESIGNER OF RECORD
REVIEWED BY
PROJECT MANAGER
FIRE PROTECTION
DEPARTMENT OF THE NAVY
NAVAL FACILITIES ENGINEERING COMMAND
SAN DIEGO, CALIFORNIA
SOUTHWEST
PHOTOVOLTAIC SYSTEM
MARINE CORPS BASE CAMP PENDLETON, CA
OVERALL GENERAL PLAN - TOPO AND BALLASTS
SIZE D
SCALE: 1" = 50'
SPEC NO.
CONSTR. CONTR. NO. N68711-05-D-4013 TO#0024
SHEET 8 OF 41
C2.0

Basis of Design for
Box Canyon PV System

ELECTRICAL

Prepared For:

Naval Facilities Engineering Command and

Marine Corps Base Camp Pendleton

Prepared By:

Engineering Partners and

AECOM

THE ENGINEERING PARTNERS, INC.
9565 WAPLES STREET, SUITE 100
SAN DIEGO, CA 92121
(858) 824-1761

Synergy Electric
"Working Together"

AECOM

System Summary

PV & ELECTRICAL SYSTEM SUMMARY

Site Details	
Site Location	Marine Corps Base Camp Pendleton
Site Description	Box Canyon Landfill
Site Latitude	33.2° N
Ambient Temperature: Record High / Low	112°F / 24°F
Ambient Temperature: Average High / Low	82°F / 40°F
Equipment Specifications	
PV Module Model	Sharp 235Wp Model NU-U235F1
Module STC DC Rating	235 Wp
Module PTC Rating	211.7
Modules per Strings	14
Strings per Combiner Box	30
Total Module Count	6,300
Total STC-DC System Size	1,480 kW
Inverter Model No.	Xantrex GT500-480 (500 kW)
Inverter Efficiency	96.5% CEC
Array Azimuth	190°
Module Tilt	15°
Interconnection Details	
Interconnection Type (Line Side or Load Side)	Line-Side Tap
Interconnection Voltage	12470v.
New Panel Rating	2000A
Main Rating	2000A
PV System Interconnection Overcurrent Protection Device Type/Rating	Bolted Pressure Switch, 2000A

Basis of Design

Abbreviations	
A	Amps
AC	Alternating Current
CEC	California Energy Commission
DC	Direct Current
I_{MP}	Maximum Power Current
I_{SC}	Short Circuit Current
NEC	National Electrical Code
PV	Photovoltaic
STC	Standard Test Conditions (1000 W/m^2)
V	Voltage
VAC	Voltage Alternating Current
V_{MP}	Maximum Power Voltage
V_{OC}	Open Circuit Voltage
Wp	Watts peak (Nameplate module output in Watts)

1. NEC Article 690 on Photovoltaics

2. NEC Article 240 on overcurrent protection

3. NEC Article 690, Section V and Article 250 on grounding

4. NEC Article 690, Section IV and Article 300 on conductor sizing

5. NEC Article 690.64 and 230.41 for interconnection

6. Source Circuit Sizing

    6.1. The maximum number of modules wired in series for a source circuit will be based on the selected module's DC Open Circuit Voltage (V_{oc}) multiplied by its open-circuit voltage temperature coefficient per NEC 690.7. The V_{oc} shall not exceed 600 VDC. Historical temperature data is obtained from the National Weather Service for Camp Pendleton, CA. Extreme low and high values will be referenced for analysis.

    6.2. This source circuit size will be confirmed with the inverter manufacturer to ensure proper functionality and performance. In case of conflict, the more stringent requirements shall be met.

7. Minimum Conductor/Type Sizing

    7.1. Design per NEC Article 690.8 (A) & (B) and NEC Table 310.16

7.2. Ground level and underground conductors will include temperature correction factors per NEC Article 310.15 and Article 690.31. Temperature data obtained from the National Weather Service will be referenced for analysis.

7.3. All conductors will be cross-referenced with 75°C ampacity table to ensure compatibility with 75°C rated terminals in ancillary equipment.

7.4. Source circuit conductors where not installed in conduit shall be USE-2 wet-rated at 90˚C or approved equal. Source circuit conductors installed in conduit shall be THWN-2 or approved equal and wet rated at 90˚C. The grounded (negative) conductor shall have a white colored insulation or be identified with white marking tape at each termination. The exception to this is the conductors which connect the modules together or conductors which are part of the modules themselves.

7.5. Output circuit wiring shall be THWN-2 or approved equal. Conductor shall be wet-rated at 90°C. It is required that the negative conductor have a white outer jacket.

7.6. AC Conductors shall be THWN-2 or approved equal. Conductor shall be wet-rated at 90°C. It is required that the three-phase conductors have color-coded jackets or taped according to the specific voltage.

7.7. Equipment grounding conductors for all circuits shall be sized per NEC Article(s) 690.45 and 250.122.

8. Conduit Type/Size/Installation

8.1. All DC source and output circuits shall be installed in conduit except conductors that connect module to module. Rigid Metal Conduit (RMC) or, where flexibility is required, Liquidtight Flexible Nonmetallic Conduit (LFNC) shall be used outdoors above ground. Rigid PVC conduit shall be used underground. Single conductors that are part of the source circuit or output circuit shall not be installed in conduit alone. Both the positive and negative sides of a circuit shall be installed in conduit with the equipment grounding conductor. The landfill cap shall not be penetrated and all conduits on the cap shall be above ground. Once the conduits leave the cap and enter the building they shall be installed underground.

8.2. Source circuit USE-2 conductors shall be permitted to be routed along PV Module frames and its associated racking system. Exposed string wiring will be secured to its associated rack and neatly routed to an enclosed NEMA-3R or better wireway located along the back of each rack.

8.3. Conduit shall be sized per NEC Article 310

8.4. Conduit spacing shall be dictated with proper application of the NEC Article 314.28: Sizing of Pull Boxes for straight, angled, and U-pulls.

8.5. Conduit spacing for vertical penetrations into enclosures shall be dictated by proper spacing of weather tight conduit fittings.

8.6. Per NEC 300.7(B), expansion fittings shall be provided where necessary to compensate for thermal expansion and contraction.

8.7. Support of RMC conduit shall be installed per NEC Article 300.18 and shall be securely fastened in place and supported per NEC 344.30(A) & (B).

8.8. There shall not be more than four (4) 90° bends between pull points.

9. Grounding

9.1. The PV Installation Grounding System shall be designed per NEC Article 690.47 and pertinent sections of Article 250. The equipment grounds shall be installed in the conduits along with the Source and D.C. output circuits. NO DRIVEN GROUND RODS WILL BE PART OF THE PV GROUNDING. There will be no conduits underground on the cap of the landfill.

10. Max DC Voltage drop of 1.5%

10.1. This is defined as the voltage drop for the maximum one way distance between a circuit source and common connection point of the PV system.

10.2. Each PV Source Circuit as defined by NEC Article 690 will have wire appropriately sized to limit the voltage drop to 1.5% or less.

10.3. Each PV Output Circuit as defined by NEC Article 690 will have wire appropriately sized to limit the voltage drop to 1.5% or less.

11. Max AC Voltage drop of 1%

11.1. This is defined as the AC voltage drop between the inverter AC output terminals and the physical point of interconnection.

11.2. The AC wire size will be selected to limit the voltage drop to be less than or equal to 1%.

12. Access and Offsets

12.1. Adapted CAL Fire Guidelines for Array Layouts

13. Array Layout

13.1. Array is composed of modular panel assemblies or racking systems each containing 28 PV modules. Panel assemblies are not rigidly connected to one another to allow for displacement due to settlement of landfill material.

13.2. Array row-to-row spacing is 10ft to allow for service and maintenance of the system.

13.3. Array will be offset from landfill edge a minimum of 15ft.

13.4. The array azimuth will be 190° to optimize power production during the peak periods. Optimal orientation was determined using PV output modeling software (PVWatts and PVSyst).

14. PV System Components

14.1. Inverters

14.1.1. Inverter(s) will be sized based on the number of PV modules in the associated array layout multiplied by both the module's PTC rating and the inverter's CEC efficiency rating.

14.1.2. Physical inverter placement will be such to minimize the DC voltage drop of the system.

14.1.3. Inverters will be housed indoors in NEMA 3R or better enclosures with adequate ventilation for cooling. Cooling and ventilation requirements will be specified by inverter manufacturer.

14.1.4. Refer to Structural Basis of Design for inverter(s) foundation and floor attachment criteria.

14.2. Combiner Boxes

14.2.1. Combiners will be sized for 30 strings (minimum) each.

14.2.2. Physical combiner box locations will be located in the solar array field strategically located to minimize DC voltage drops and to allow for easy access. Care will be taken to ensure the combiner boxes will not cast shadows on any PV modules.

14.2.3. Combiner boxes will be in a minimum NEMA 4X enclosure and will be installed in either a vertical or horizontal position.

14.3. Data Acquisition System (DAS)

14.3.1. The DAS shall be Fat Spaniel Technologies Basic Commercial PBI-Compliant monitoring service package that provides revenue grade monitoring and reporting for 3-phase systems rated 20 kW DC and above.

14.3.2. System will provide information in real time of kWh produced, daily peak kW, hours of operation, inverter status and weather information (ambient temperature, wind speed, and irradiance on W/m^2).

14.3.3. Meter: The meter provided will be compatible with Camp Pendleton's RF and hand held meter reading system.

14.3.3.1. Accuracy of +/- 5%

14.3.3.2. The meter will comply with SDG&E's requirements and be approved and listed as eligible equipment by the CEC.

14.3.3.3. As part of the metering system, the following hardware will be included: Meter, Current Transformers, Voltage Transformers

14.3.4. Weather Station:

14.3.4.1. Ambient Temperature Sensor

14.3.4.2. Cell Temperature Sensor

14.3.4.3. Wind Speed

14.3.4.4. Irradiation

15. Lightning Surge Protection

15.1. In compliance with NEC Article 280, surge arresters required for systems over 1kV.

15.2. The surge protection shall be a device in the major PV system equipment. The inverters shall have an integrated surge protection device on both DC and AC sides.

15.3. Surge protection shall not invalidate PV system equipment warranties.

16. Inverter Output circuits

16.1 The Inverter output circuits shall be transformed to 480v., at the inverter, by a transformer attached to the inverter and sized to transform the maximum output of the inverter. The transformer output conductors shall be considered "Inverter Output Circuits".

16.2 Inverter output circuits and combined AC output circuits from all (3) inverters shall be sized in accordance with NEC Article 690.8 (A)(3) and Article 310.16

16.3 Output circuit overcurrent protection shall be sized in accordance with NEC Article 690.8 (B)(1).

16.4 The output of the 3 inverters shall combine in a switchboard. The main switchboard disconnecting switch shall be the "Utility Required Disconnect".

16.5 In the combining switchboard there shall be provisions for a dedicated meter for the utility (Net Generating Output Meter).

17. Grid Tie System

17.1 The Grid Tie System shall consist of a medium voltage transformer, 4-way oil filled medium voltage switch, underground conductors to a medium voltage transmission line, and fused pullouts connecting the system to the grid. This equipment will be located off the landfill cover. The transformer and 4-way oil filled switch shall be placed next to the new inverter building.

17.1.1 The medium voltage transformer shall be sized to carry the maximum possible load of the inverters. This transformer shall meet Camp Pendleton Standards.

17.1.2 The 4 way switch shall meet Camp Pendleton Standards and shall be installed so as to provide for future use by another PV system of equal size.

17.1.3 The underground conductors shall be installed in a conduit duct bank that in accordance with the NEC and Camp Pendleton standards.

17.1.4 The connection to the grid shall be mounted on a cross arm installed on an existing transmission pole. The hardware shall meet the Utility standard OH 1432.2.

18. Inverter Building

18.1 The inverter building shall be a CMU building and meet Camp Pendleton BEAP requirements. This building shall be constructed off the cap and outside the limits of the landfill cover.

18.2 The new building shall be strategically located south of the landfill area and placed relatively close to the PV array segments it serves to minimize power losses.

18.3 Conduits entering and leaving the building including the DC power conduits from the PV arrays and the AC output conduits to the interconnection point shall be underground. Note: Only DC power conduits located on the landfill cover will be above ground. Once off the landfill cover and prior to entering the building, the DC power conduits will transfer to underground.

18.4 The building's interior space shall be air conditioned.

18.5 The heat from the top of the inverters shall be ventilated to the outside.

Calculations

1. Voltage Correction Factor (VCF):

$$VCF = MTC * (T_T - T_L) = -0.351 * (25 - (-6.7)) = -11.13\%\ or - 0.111 \quad (1)$$

Where: MTC ≡ Module Open Circuit Temperature Coefficient (%/°C)
Sharp Model NU-U235F1 (-0.351%/°C)
T_T ≡ Standard Test Temperature (25°C)
T_L ≡ Low Temperature for Camp Pendleton (-6.7°C)

2. Maximum Array Voltage (V_{max}):

$$V_{max} = (SS * V_{OC}) * (1 - VCF) = (14 * 37.0) * (1 - (-.111)) = 575.5\ V \quad (2)$$

Where: SS ≡ String Size
V_{OC} ≡ Open Circuit Voltage for Sharp NU-U235F1
VCF ≡ Voltage Correction Factor for Sharp NU-U235F1
V_{max} < 600 V

3. Inverter Size:

$$Size\ (W) = QTY * Module\ Power * \eta_{inv} \quad (3)$$

$$Size\ (W) = 2{,}100 * 211.7 * 0.965 = 429{,}010\ W$$

Where: QTY ≡ Module Quantity per System
Module Power ≡ Module PTC Power Rating
η_{inv} ≡ Inverter CEC Efficiency

4. DC Voltage Drop (V_D):

$$V_D = I * R * L * 2 \quad (4)$$

$$\%\ Drop = \frac{V_D}{V} * 100 \quad (5)$$

Where: I ≡ Operating Current (A), String Circuit = 7.84A, Output Circuit = 235.2A
R ≡ Wire Resistance (Ω/1000')
L ≡ One Way Conductor Length (ft)
V ≡ PV Array Operating Voltage (V), V_{mp} = 420V

Temperature Correction Factor for DC Resistance

$$R_2 = R_1 * (1 + \propto * (T_2 - 75)) \quad (6)$$

Where: R_2 ≡ Temperature Corrected Resistance (Ω/1000')

$R_1 \equiv$ Resistance Value at 75°C from NEC Chapter 9, Table-8 (Ω/1000')
$\alpha \equiv$ Resistivity Factor for Copper at 75°C (0.00323)
$T_2 \equiv$ Maximum Ambient Temperature for Camp Pendleton (45°C)

Wire Size	R_1 (Ω/1000')	R_2 (Ω/1000')
# 10 Cu	1.24	1.12
4/0 Cu	0.0608	0.0549
250 kcmil Cu	0.0515	0.0465

Table-1: Temperature Corrected Resistance Values

5. Maximum One-Way Distance Allowed (V_D < 1.5%)

Combining Equations (4) & (5) and solving for maximum length (L) results in the following relation:

$$L = \frac{1.5*V}{100*2*I*R_2} * 1000 \quad (7)$$

Wire Size	Operatin g Current, (A)	R_2 (Ω/1000')	Voltage (V)	Voltage Drop (%)	Maximum Circuit Length (ft)
#10 Cu	7.84	1.12	420	1.5	358
(2) 4/0 Cu	235.2	0.0549	420	1.5	488
(2) 250 kcmil Cu	235.2	0.0465	420	1.5	577

Table-2: Maximum Circuit Distance

6. DC Conductor Size - Conductor Sizing is based on the Sharp model NU-U235F1 photovoltaic module. The following information is obtained from equipment data sheets:
   a. Short Circuit Current (I_{SC}) – 8.6A
   b. Open Circuit Voltage (V_{OC}) – 37.0V
   c. Maximum Power Current (I_{pm}) – 7.84A
   d. Maximum Power Voltage (V_{pm}) – 30.0V

Each string has fourteen (14) modules wired in series to produce an open circuit voltage of 518V.

Thirty (30) strings are combined in parallel to provide a PV output circuit. These circuits have a short circuit current of 258A.

Maximum DC Circuit Current (I_{max}):

$$I_{max} = I_{sc} * 125\% \quad (8)$$

Minimum Conductor Ampacity (I_{req}) Required:

$$I_{req} = I_{max} * 125\% \quad (9)$$

Wire Size (AWG)	I_{sc} (A)	I_{max} (A)	Required Wire Ampacity, I_{req} (A)	Wire Ampacity Rating (75°C) (A)	Allowable Ampacity (A)
#14	8.6	10.75	13.44	20	15
(2) #4/0	258	322.5	402.5	460	460

Table-3: Minimum DC Conductor Requirement

Specific conductor selection is summarized in Table-4 below.

Sheet(s)	Callout ID	Short Circuit Current (I_{SC})	Maximum Continuous Circuit Current (A)	Wire Size and Type	Wire Ampacity (90°C) (A)	Correction Factors	Adjusted Wire Ampacity, (A)	Fuse Size (A)	Fuse Location	Notes
E2.1, E2.2, E2.3	A	8.6	10.75	#10 USE-2 or THWN-2	40	0.87 x 0.40	13.92	15	Combiner Box	1, 2
E2.1	B	258	322.5	(2) #4/0 THWN-2	520	0.87 x 0.8	361.9	450	DS-11	1, 3
E2.1	C	258	322.5	(2) #4/0 THWN-2	520	0.87 x 0.8	361.9	450	DS-11	1, 3
E2.1	D	258	322.5	(2) #4/0 THWN-2	520	0.87 x 0.8	361.9	450	DS-12	1, 3
E2.1	E	258	322.5	(2) #4/0 THWN-2	520	0.87 x 0.8	361.9	450	DS-12	1, 3
E2.1	F	258	322.5	(2) #4/0 THWN-2	520	0.87 x 0.8	361.9	450	DS-13	1, 3
E2.2	G	258	322.5	(2) #4/0 THWN-2	520	0.87 x 0.8	361.9	450	DS-21	1, 3
E2.2	H	258	322.5	(2) #4/0 THWN-2	520	0.87 x 0.8	361.9	450	DS-21	1, 3
E2.2	I	258	322.5	(2) #4/0 THWN-2	520	0.87 x 0.8	361.9	450	DS-22	1, 3
E2.2	J	258	322.5	(2) #4/0 THWN-2	520	0.87 x 0.8	361.9	450	DS-22	1, 3
E2.2	K	258	322.5	(2) #4/0 THWN-2	520	0.87 x 0.8	361.9	450	DS-23	1, 3
E2.3	L	258	322.5	(2) #4/0 THWN-2	520	0.87 x 0.8	361.9	450	DS-31	1, 3
E2.3	M	258	322.5	(2) #4/0 THWN-2	520	0.87 x 0.8	361.9	450	DS-31	1, 3
E2.3	N	258	322.5	(2) #4/0 THWN-2	520	0.87 x 0.8	361.9	450	DS-32	1, 3
E2.3	O	258	322.5	(2) #4/0 THWN-2	520	0.87 x 0.8	361.9	450	DS-32	1, 3
E2.3	P	258	322.5	(2) #4/0 THWN-2	520	0.87 x 0.8	361.9	450	DS-33	1, 3

Table-4: Conductor Selection Table

Notes:
1. Temperature Derate for 112°F.
2. Conduit Fill Derate Factor – less than forty (40) current carrying conductors per raceway.
3. Conduit Fill Derate Factor – four (4) current carrying conductors per raceway.

ATTACHMENT 2

Agency Correspondence

Response to DTSC Comments on the Revised Draft Explanation of Significant Difference Operable Unit 3 Record of Decision Installation Restoration Site 7, Marine Corps Base Camp Pendleton, dated April 2010

#	Section	Comment	Response to Comment
Response to Comments from Tayseer Mahmoud dated April 21, 2010			
1	Signatures	Greg Holmes will sign the ESD instead of John Scandura. Greg Holmes, Unit Chief Brownfields and Environmental Restoration Program - Cypress Department of Toxic Substances Control	The authorized DTSC signatory will be changed from Mr. Scandura to Mr. Holmes.
2	1.0 Introduction Line 7	The sentence reads " direct current (DC) solar photovoltaic (PV) panels covering an area approximately six acres...". Please change the sentence to read "direct current (DC) solar photovoltaic (PV) panel system covering an area approximately six acres..".	The sentence will be changed to "direct current (DC) solar photovoltaic (PV) panel system covering an area approximately six acres."
3	4.0 Description of Significant Differences 4th bullet	The second sentence of bullet 4 states that the PV rack will also consist of 28 PV modules and have a 15 degree tilt oriented 190 degrees. (to what or from what?).	The sentence will be reworded for better clarification to state: …have a 15 degree tilt from horizontal and oriented 190 degrees (southerly direction)
4	4.0 Description of Significant Differences 8th bullet	The foundation support will be above ground (no penetration of cover) and consists of a gravel bed. How thick is the gravel bed?	The gravel bed is approximately 3 to 10 inches thick.
5	4.0 Description of Significant Differences last paragraph, page 2 2nd sentence:	The sentence states that Solar PV panels will set directly on ET cover structure. The panels are not directly on ET cover if they will be on gravel.	The sentence will be reworded to state that the PV panels will set directly on gravel.
6	Table 2 Summary for Vegetation	List or ID the plant species. Clarify if the plants will be irrigated and how much water will be needed.	The list of plant species as specified in the DCR will be added to Table 2. The plants selected are not required to be irrigated. These plants are drought tolerant plants.

Response to DTSC Comments on the
Revised Draft Explanation of Significant Difference Operable Unit 3 Record of Decision Installation Restoration Site 7,
Marine Corps Base Camp Pendleton, dated April 2010

#	Section	Comment	Response to Comment
7	Section 5.0 Regulatory Agency Comments:	Please include a statement regarding the PV system if it has been done anywhere else in the nation. If so, what were the results?	Fort Carson Landfill, Colorado, is a 2 MW PV project on a former landfill site, The PV array is ground-mounted, fixed-tilt covering ~12 acres, 6.5 of which overly the former landfill. Fort Carson continues to be responsible for landfill monitoring and maintenance. According to Vince Guthrie, they have had no issues with vegetation or drainage. You may contact Vince Guthrie, Utility Programs Manager, CEM Fort Carson, Directorate of Public Works at t719-526-2927.
8	NA	During the 99th FFA meeting at Camp Pendleton (February 18, 2010), AECOM Consultants stated that the site wind conditions controls the design and not the seismic conditions. However, there was no discussion or analyses to that effect in the Design Basis Report or the Design Consideration Report.	Calculations for both wind and seismic design critera are provided in Section 3 of the BOD, Structural (starts on page 18 of the .pdf document). The design criteria (conditions, resulting forces, and safety factors) for wind and seismic including checks to verify that the design of the rack and ballasts provide adequate stability.

Response to RWQCB Comments on the Revised Draft Explanation of Significant Difference Operable Unit 3 Record of Decision Installation Restoration Site 7, Marine Corps Base Camp Pendleton, dated April 2009 (Reference 5090 Ser RAE30.TM/115 DOD100037700:kdorsey)

#	Section	Comment	Response to Comment
Response to Comments from Kelly Dorsey dated April 29,2010			
1		The Structural Basis for Design contains two sets of structural calculations. Please clarify why two sets of calculations and designs are included. If only one design will be used, please include only the calculations for the selected design. The first set of calculations presented on Pages 21 to 32 is inadequate for the following reasons: a. It appears that the footings shown in this design will puncture the landfill cover. The footing design shown on page 30 consists of a 36-inch high, 12-inch diameter concrete pier. No schematics showing the piers in relation to the landfill cover are provided. Based on the schematics on page 22, 23, 26, and 27, which show above grade features of the rack systems and do not include the piers, we assumed that the piers are designed to extend 36-inches below grade, which would puncture the cover. Either select an alternate footing design, or provide more detailed drawings illustrating that the footings as designed will not puncture the landfill cover. b. The force analysis shown on page 27 is unclear and lacks sufficient detail to allow for verification. The schematics on page 27 appear to be truss models. Truss members can only support axial forces and cannot support shear forces. The model includes a shear force in the front and rear caps (at points C and D). A description of these members is not provided. The axial direction of these members and how these members can support shear forces is not clear. If you wish to use this design, provide further detail into the structural design, provide a schematic for the front and rear caps, and clarify how the shear forces are being addressed. A spot check of the forces at point G for the down force	**For comment a.:** A clarification of the structural analyses will be provided. The pdf file appeared to include information that was not intended for the structural design calculations. Ballasts are proposed for the PV system. The Old Castle Calculations reflect the structural calculations for the ballasts. Unirac footings will not be used therefore no piers penetrating the existing ET cap are proposed. **For Comment b.:** The RWQCB comment discusses concern over the structure being a truss design, with bending of the truss members and induced shear into the connections. The actual design is not a truss. It is designed as a simple post and beam, with a diagonal brace for structural stability. In the perpendicular direction to the frame, there is a 3 inch pipe above the front and the rear legs, with diagonal bracing perpendicular to the frame, as well. See the Unirac Design Package included in the final BOD, Revision 4, 11 pages, dated May 20, 2010. The rail was analyzed as a beam for the applied bending and shear forces and found to be adequate for the loads. Likewise, the beam to column (leg) connections, called front and rear caps, were checked and found to be adequate for applied loads. Similarly, the top rail, vertical legs and the diagonal brace were analyzed for buckling and found to be adequately sized. The front and rear legs are connected to a concrete ballast, also sized for the applied loads. The steel framework components will be measured and constructed on site, so no initial built in stresses will be present. Details of all connections

Response to RWQCB Comments on the
Revised Draft Explanation of Significant Difference Operable Unit 3 Record of Decision Installation Restoration Site 7, Marine Corps Base Camp Pendleton, dated April 2009
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#	Section	Comment	Response to Comment
		load case indicated that the horizontal forces were not balanced. Please provide hand calculations for one load case to demonstrate that the structure is stable.	can be seen in the accompanying construction drawings and in the Unirac Installation Manual 302.
2		If differential settlement occurs due to the 12 to 18 inches of municipal solid waste decomposition, please summarize how positive drainage will be maintained underneath the photovoltaic (PV) panels.	Ponding that occurs on ET cap by differential settlement will be addressed by the Post-Closure Monitoring and Maintenance Plan (PCMMP). Differential settlement occurring at the ballast locations will be addressed by the PV system O&M Plan in this manner: If the area of differential settlement includes one or more ballasts, the solution will also include removing the affected ballast(s), gravel, and panel section(s) as necessary to perform the maintenance. Then complete the work on the soil cap per the PCMMP, and place the gravel, ballast(s), and panel section(s) back to their original position(s). Cover settlements will be repaired and regraded to provide positive drainage. PV Panel frames will be re-leveled as necessary.
3		Please re-run the deformation analysis adding the load from the PV panels and using the same parameters used in the analysis completed in the 2000 U.S. Army Corps of Engineers report. The deformation analysis from 2000 is cited in Section 2.2.1 of the Design Considerations Report. The 2000 deformation analysis predicted 6.3 inches of displacement without the PV panels; however, the stability analysis on page 66 of the Basis of Design only predicted 1 to 2 inches of displacement with the PV panels in place. Please explain the apparent discrepancy.	The current deformation analysis is based on the 20-foot tall slope near the PV Panels. The location will be shown per Comment No. 4 below. The 2000 deformation analysis was based on the more critical 40-foot tall slope located on the north side of the cover system and not near the PV Panel system. Greater deformation of the north slope would be expected and is consistent with the results. An additional difference in the analyses is related to the difference in the soil parameters between the 2000 USACE analysis and the recently completed analysis. .
4		Provide a geologic cross section depicting the most critical (least	Agree. A geologic cross section was provided to the

#	Section	Comment	Response to Comment
		stable) slopes, geologic structure, stratigraphy, and subsurface water conditions. The cross sections included on pages 68 and 69 appear to be simplified schematics, and do not contain the needed level of detail. In addition to the figure, please describe any details not readily visible in the figure, such as the angle of the side slope and top deck.	RWQCB on 18 May 2010 for review and is provided in the final BOD. The critical cross section was selected for the greatest slope height along the PV array. The slope was modeled at 2.5h to 1 v and a slope height of 20 feet was selected. A uniform surcharge was applied conservatively to the edge of the slope.
5		Summarize the analyses presented on figures 68 and 69. Ensure that the following items are included in the summary or clearly labeled on the figure: a. The type of analysis (static, or pseudo-static), b. The name of the computer model, c. References for the input parameters, d. Output of the model, e. A map showing the location of the critical cross section, and f. An explanation of how the critical cross section was determined.	The items for comments a through f were provided to the RWQCB on 17 May 2010 and is included in the final BOD. **For comment a.:** Both static and pseudo-static analyses were performed. **For comment b.:** The computer model used to evaluate the slope stability is Slope/W. **For comment c.:** References for the input parameters have been included in the final BOD. **For comment d.:** The output of the model is included in the final BOD. **For comment e.:** A map showing the location of the critical cross section was provided to the RWQCB on 17 May 2010 and is included in the final BOD. **For comment f.:** The critical cross section was selected for the greatest slope height along the PV array. The slope was modeled at 2.5h to 1 v and a slope height of 20 feet was selected. A uniform surcharge was applied conservatively to the edge of the slope. The geologic cross section from the 2000 USACE report which corresponds to the area of interest is included in the final BOD. The groundwater table and approximate limits of the project are highlighted.
6		The cross sections on page 68 and 69 depict an oversimplified	A series of analysis was performed to model a

#	Section	Comment	Response to Comment
		monolithic cover, and should be modified to include all layers of the cover including the clay layer. Define the predicted failure surface and provide an explanation of which layers will be affected in a predicted failure. At a minimum the model must include all layers included in the stability analysis conducted in 2000. The cohesion of the evapotranspirative cover should be set at 0 in both models or the model parameters from the original stability analysis conducted in 2000 should be used.	saturated and drained condition for the static and pseudo static cases. The soil parameters selected are based on a cohesion of ET cover set to 0 psf for both models. For the drained case a friction angle of 28 degrees will be analyzed.
7		Include depth to water on the figures on page 68 and 69. Verify that the model was run under fully saturated conditions, which represent a worst case scenario. Re-run the analysis if needed.	An additional slope stability analysis will be performed assuming fully saturated conditions only in the ET cover zone and for static and pseudo static conditions. The purpose of the ET cover is to prevent water from infiltrating into the waste; therefore we do not think that it is reasonable to model a saturated condition in the waste. The risk of having a saturated zone during a MCE event is extremely remote.
8		Justify the use of the Makdisi-Seed displacement analysis. The Makdisi-Seed model is a simplified model to compute permanent deformation of earth darns and embankments. Modeling the multi-layer cover system as a monolithic earthen dam may not be appropriate.	The Makdisi-Seed simplified displacement analysis was developed for earth and embankment dams. However, it was also adopted in the geo-profession as a standard-of-practice for landfill design relative to slope deformations. This is the method that was used for the displacement estimates presented in the 2000 USACE report. The method is referenced in the *RCRA Subtitle D (258) Seismic Design Guidance for Municipal Solid Waste Landfill Facilities* document. It is also referenced in ASCE documents including *Seismic Stability and permanent Displacement of Landfill Cover Systems* by Ling and Leshchinsky as an acceptable method for landfill slope deformation evaluations.